Courtesy San Jose Chamber of Commerce

Use of Water in California

STATE OF CALIFORNIA
GOODWIN J. KNIGHT
GOVERNOR

PUBLICATION OF
STATE WATER RESOURCES BOARD

Bulletin No. 2

WATER UTILIZATION AND REQUIREMENTS OF CALIFORNIA

Volume I
TEXT

June, 1955

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GOODWIN J. KNIGHT
GOVERNOR

STATE OF CALIFORNIA
STATE WATER RESOURCES BOARD
PUBLIC WORKS BUILDING
SACRAMENTO 5, CALIFORNIA

June 30, 1955

ADDRESS ALL COMMUNICATIONS TO THE SECRETARY

HONORABLE GOODWIN J. KNIGHT, *Governor, and*
Members of the Legislature of the
State of California

GENTLEMEN: I have the honor to transmit herewith Bulletin No. 2 of the State Water Resources Board, entitled "Water Utilization and Requirements of California," authorization of which was initiated by Chapter 1541, Statutes of 1947.

Under the provisions of the cited statute and subsequent budget acts, the Legislature directed the State Water Resources Board to make an investigation of the water resources of California and to formulate plans for the orderly development of such resources. Accordingly, the Board adopted a program of investigation and a budget at its regular meeting on September 5, 1947. Appropriations required for continuance of the work have been made by the Legislature through the Fiscal Year 1955-56. The investigation is being conducted by the Division of Water Resources of the Department of Public Works, under the direction of the State Water Resources Board.

Bulletin No. 2 presents results of a comprehensive analysis of present and probable ultimate use of water in California for irrigated agricultural, domestic, industrial, and other beneficial purposes. The bulletin contains estimates of the gross water requirements for all beneficial purposes, and of the amount of supplemental water required for satisfaction of present and probable ultimate needs throughout California.

Very truly yours,

Clair A Hill
CLAIR A. HILL
Chairman

ACKNOWLEDGMENT

Valuable assistance and data used in the investigation were contributed by agencies of the Federal Government and of the State of California, by cities, counties, public districts, and by private companies and individuals. This cooperation is gratefully acknowledged.

Special mention is made of the helpful cooperation of the following:

Bureau of Reclamation, United States Department of the Interior
Forest Service, United States Department of Agriculture
Fish and Wildlife Service, United States Department of the Interior
Soil Conservation Service, United States Department of Agriculture
Geological Survey, United States Department of the Interior
Federal Power Commission
California Department of Fish and Game
California Public Utilities Commission
University of California at Berkeley and at Davis
East Bay Municipal Utility District
Hetch Hetchy Water Supply, Power and Utilities Engineering Bureau, City of San Francisco
Metropolitan Water District of Southern California
Department of Water and Power, City of Los Angeles
San Diego County Water Authority
City of San Diego
Pacific Gas and Electric Company
Southern California Edison Company

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ORGANIZATIONAL CHANGES

At the time the investigation reported upon in this bulletin commenced, Royal Miller was Chairman of the State Water Resources Board, and continued in that capacity until January 7, 1949, when he resigned as Chairman but continued to serve as a member of the Board until January 15, 1953. Other members of the Board at the initiation of this study were H. J. Cozzens, B. A. Etcheverry, C. A. Griffith, R. V. Meikle, and Phil D. Swing. The remaining vacancy on the Board was filled by the appointment of Clair A. Hill on July 20, 1949. Mr. Griffith succeeded to the position of Chairman upon the resignation of Mr. Miller. W. P. Rich was appointed to the Board on October 25, 1953, to fill the vacancy resulting from Mr. Miller's retirement. Mr. Cozzens retired from the Board on January 1, 1954. The death of Mr. Etcheverry on October 26, 1954, removed from public life one of its outstanding engineers and citizens, and one whose wise counsel will be missed in the future. Arnold Frew was appointed to the Board on February 10, 1955, replacing Mr. Cozzens. Mr. Hill became Chairman on May 13, 1955, succeeding Mr. Griffith, who remained as a member of the Board. The vacancy left by the death of Mr. Etcheverry was filled by the appointment of W. Penn Rowe on May 25, 1955.

Edward Hyatt, former State Engineer and ex-officio Secretary and Engineer to the Board, retired from state service on January 31, 1950, and was succeeded by A. D. Edmonston. Mr. Hyatt died on June 17, 1954.

Conduct of the State-wide Water Resources Investigation was under the direction of P. H. Van Etten, Principal Hydraulic Engineer of the Division of Water Resources, from the initiation of studies for Bulletin No. 2 in 1948 until January 31, 1950, when he assumed the duties of Assistant State Engineer. T. R. Simpson, Principal Hydraulic Engineer, then assumed responsibility for direction of the investigation. Since Mr. Simpson's resignation from the Division of Water Resources on September 15, 1950, the investigation has been directed by W. L. Berry, Principal Hydraulic Engineer.

PREFACE

CURRENT STATUS OF WATER SUPPLY DEVELOPMENT AND REQUIREMENTS IN CALIFORNIA

Studies for the State-wide Water Resources Investigation to date indicate that California is faced with a substantial and rapidly increasing deficiency in developed water supplies as related to requirements for water. The urgency in this current problem is believed to be sufficient to warrant a statement in this respect prefatory to presentation of the material in this bulletin.

Data set forth herein pertaining to so-called "present" conditions of water utilization and requirement in California actually relate to the status of development as of about 1950. They are based largely upon field surveys conducted in 1949 and 1950, reports of cooperating agencies for 1950, and records of water supply and use as secured from operating utilities or as estimated by the Division of Water Resources for 1950 development.

During the intervening years since 1950 the necessary office studies and analyses have been conducted and this bulletin prepared for publication. However, in this same period a very significant growth has occurred throughout California. Reliable estimates indicate that the population of the State has increased by about 18 per cent since 1950 to a present total of nearly 12,500,000, and that the net irrigated area has increased by about 13 per cent to some 7,750,000 acres.

In 1950 the estimated mean seasonal deficiency in water supply development throughout the State amounted to nearly 2,700,000 acre-feet. While in most instances the lands representing this shortage were physically served with water, it was necessary to draw on diminishing reserves, principally ground waters, in order to meet the deficiency. Such perennial overdraft has been increasing rapidly of recent years, and has resulted in accelerated lowering of ground water levels in many parts of the State. It is now evident that continuing overdrafts will not only drastically reduce the reserves in storage, but in many instances will irreparably damage the immensely valuable ground water reservoirs.

Increased water requirements due to the growth of California since 1950 are estimated to aggregate about 3,200,000 acre-feet per season. However, since 1950, new water supplies have been made available through the Friant-Kern and Delta-Mendota Canals, and other recently constructed projects, in amounts which have partially offset the increased use.

In some places the necessary additional water supplies could now be obtained by increasing imports within the potential capacity of existing works. As an example, supplemental water now needed in the South Coastal Area, excepting only Ventura County, could be provided by increasing the imports from the Colorado River.

Based upon reasonable forecasts of growth of the State over the next 10 years, it is indicated that the shortage in water supply development could amount to more than 10,000,000 acre-feet per season by 1965, even taking into account increasing importation from presently developed water sources.

There is further reason for anxiety at the lag in timely water resource development in California. The estimated yields of our present works, as well as those planned for the future, are necessarily based on the assumption that the short recorded history of natural water occurrence will repeat itself in the future. Even if this should prove to be true, it is likely that there will be recurrence of extended drought periods such as have been experienced in the past, during which the water supply of the State over a number of years has averaged only a little more than 50 per cent of the recorded mean. If a severe drought should come concurrently with deficiencies in water supply development such as now exist, it could create widespread havoc and even economic disaster throughout California. Futhermore, there is no reason to believe that drought conditions of the future could not be more intense and further extended than those of the short recorded past.

CHAPTER I

INTRODUCTION

This bulletin is the second of a series presenting the results of continuing surveys and studies being made under authorization of the Legislature and direction of the State Water Resources Board, with the objective of solving what is perhaps the most basic economic problem facing the people of California. That problem pertains to the conservation, control, and utilization of our abundant water resources for the greatest public benefit.

An earlier publication of the State Water Resources Board, Bulletin No. 1, "Water Resources of California," which was released in 1951, brought together in one volume the principal basic data that had been accumulated up to 1947 regarding the occurrence of water in California, and constituted an inventory of the water resources of the State. In logical sequence, this present volume comprises a determination of the present use of water throughout California and of the probable ultimate water requirement. Concurrently with the preparation of these first two bulletins in the series, work has progressed on the remaining and principal phase of the investigation: formulation of "The California Water Plan," a comprehensive plan for the fullest practicable conservation, control, protection and utilization of the water resources of California.

NEED FOR DETERMINATION OF PRESENT USE OF WATER AND OF ULTIMATE WATER REQUIREMENT

The continuing rapid development of California, which is evidenced by growth of population, expansion of industry, and increase in irrigated agriculture, has resulted in a greatly increased requirement for water. The population grew from 6,900,000 in 1940 to about 10,600,000 in 1950, and the 1954 population is estimated to be well over 12,000,000. This new population has imposed large additional demands upon agencies supplying water for domestic purposes. The recent industrial development of California has proceeded at an even more rapid rate than the growth of population. While industrial water requirements vary over wide limits depending upon type and location of the industry, the average use of water in a typical industrialized area is about five times that in an equal area devoted to domestic residential purposes. Thus, the increase in industrial development has imposed heavy demands upon water supply agencies. However, by far the greatest requirement for water in California is for the irrigation of agricultural crops. Coincident with World War II and continuing at an unabated rate to the present date, there has been rapid expansion of the area devoted to irrigated agriculture. There were about 7,000,000 acres under irrigation in this State as of 1950, according to field survey data. This constitutes an increase of roughly 1,500,000 acres since 1944. Irrigated lands require about 90 per cent of the water consumptively used within California and impose the most important draft upon the water supply.

The general location of presently irrigated lands of California, as well as those considered suitable for future irrigation development, are shown on Plate 1, entitled "Water Service Areas for The California Water Plan." Plate 2, entitled "Growth of Population and Cultivated and Irrigated Lands of California," depicts graphically the growth of population, irrigation, and cultivated agricultural areas for the entire State by decades from 1850 to 1950. The data upon which this plate was based were largely derived from publications of the United States Bureau of the Census.

In general, the responsible public and private agencies, as well as the people of California, have been aware during recent years of the urgent need for water resource development, and have taken steps as they became necessary to meet the increasing water requirements. In certain instances this has resulted in the farsighted construction of outstanding conservation and distribution works, and in others in the enlargement and expansion of existing facilities. Also, there has been major construction of hydroelectric power facilities and of flood control works. In many cases the developments have been designed and operated to enhance the recreational opportunities of the community and in the interest of the preservation and propagation of fish and wildlife. However, in large and important areas of California the new requirements for water have been met only by increasing the draft upon water stored in natural underground reservoirs at a rate beyond the replenishment to these basins. As a consequence, many such areas face the certainty of failing water supplies unless supplemental water is provided, and there is real danger of permanent and irreparable damage to the valuable ground water reservoirs through the introduction of water of inferior quality.

It seems entirely probable that the economic, climatic, and other factors that have established the present pattern of growth of population, industry, and agriculture in California, will continue in the future. It is even more certain that significant growth of the State can only be made possible by further development of our water resources sufficient to provide for the serious present deficiencies, as well as for the probable large added requirements of the future. Furthermore, experience indicates that such future water resource development should be based upon comprehensive and coordinated planning, state-wide in its scope, in order that all parts of California may share equitably in the available water resources, and in order that no area shall suffer through want of water. It was in recognition of these important considerations that the Legislature authorized the State Water Resources Board to conduct the state-wide investigation of water resources reported in this current series of bulletins.

Several investigations of the water resources of California have been made in the past, but none were truly comprehensive in scope. Succeeding years have added to the basic records and generally to the knowledge of the water resources of the State. It is for this reason, and because planning for the future must start with a thorough understanding of the location, amount, and quality of the waters of the State, and of physical conditions which determine their occurrence and availability, that the inventory of water resources contained in Bulletin No. 1 was compiled and published. Equally important to future planning is an understanding of the location, amount, and nature of the present development and use of water throughout the State, of the probable future use of water, and of the ultimate supplemental water requirement, which factors provide the subject matter of this bulletin.

AUTHORITY AND FUNDS FOR INVESTIGATION

The State Water Resources Act of 1945, as amended by Chapter 908, Statutes of 1947, invested in the State Water Resources Board broad powers to initiate and conduct investigations of the water resources of the State. Section 17(a) of the amended act reads as follows:

> "The Water Resources Board is authorized to conduct investigations of the water resources of the State; to formulate plans for the control, conservation, protection, and utilization of such water resources, including solutions for the water problems of each portion of the State as deemed expedient and economically feasible; and to render reports thereon."

Chapter 1541, Statutes of 1947, appropriated $140,000 to the Board for expenditure during the Fiscal Year 1947-48 in conducting investigations and otherwise carrying out the provisions of the State Water Resources Act. The Budget Acts of 1948 and subsequent years through 1954 have made appropriations for continuance of the investigation and for preparation of reports.

HISTORY OF WATER DEVELOPMENT IN CALIFORNIA

History of the use of water in California starts with the Spanish missions in the final third of the eighteenth century. Profiting by their experience in arid Baja California, the padres established most of the Alta California missions where water for irrigation was available. Except for some small Indian cultivations along the west bank of the Colorado River, it was in the mission "gardens" of fruits and vegetables, and perhaps in occasional fields of grain, that irrigation in California had its beginnings. Even yet, a century and a half later, remnants of mission works to supply irrigation and domestic water may be seen, notably at San Diego Mission Dam on San Diego River, and at Santa Barbara Mission Dam and Reservoir above Santa Barbara.

Acreage irrigated at the Spanish missions was small, yet it provided an important object lesson for American and European settlers who began arriving in California in the 1830's and 1840's. During the first two decades of American occupation, from 1850 to 1870, settlers in the southern part of California built small ditches diverting from streams of the coastal plain, mainly in the San Gabriel and Santa Ana River Basins. In the northern and central parts of the State water was also diverted from streams or obtained from artesian flows, and to a limited extent was pumped from streams with steam-driven pumps. In the Sierra Nevada foothills water was acquired from mining ditches, irrigation being accelerated by the expansion in population that accompanied and followed the Gold Rush.

The first irrigation was from nearby streams, without storage, and lands irrigated were limited to those that could be watered from low summer flows. In the southern part of California, however, the need for storage reservoirs was early recognized, and several important dams, including Bear Valley, Hemet, Sweetwater, and Cuyamaca, were constructed or begun in the 1880's. In the remainder of the State all major storage reservoirs primarily for irrigation have been provided since 1900. A number of these, such as Melones, Don Pedro, and Exchequer, were made feasible by the hydroelectric power to be developed with the water stored.

Early irrigators following Spanish and Mexican days were mainly individuals. By 1856, however, a "commercial" company had constructed canals to irrigate wheat near Woodland in Yolo County, and about that time groups of settlers were joining together to build ditches in the south. Construction of larger irrigation works by development companies and cooperatives was well under way by the 1870's and 1880's, both in the southern part of the State and in the central and southern parts of the San Joaquin Valley. In 1887 the original Wright Irrigation District Act was passed by the Legislature, partly as a result of prior court decisions regarding water rights which were adverse to irrigation development. By following the general pattern of this act, the principal irrigation expansion in California has been accomplished during the past 30 or 40 years. Owing largely to authority granted by the Legislature to irrigation and similar districts to finance, construct, and operate irrigation works, and also because of the activities of many individuals, cooperatives, and water utilities, irrigated agriculture has attained its present position of dominant importance to the economy of the State. The locations of all irrigation and water storage districts, the more important of the many types of public districts responsible for development of irrigation water in California, are shown on Plate 3, "Irrigation and Water Storage Districts."

The continuing increase in use of water for irrigation in California is indicated in the following tabulation showing historical growth of the area devoted to irrigated agriculture:

Year	Area irrigated, in acres	Source of information
1880	Less than 400,000	Report of State Engineer, 1880
1890	1,004,233	Reports of United States Census
1900	1,446,114	Reports of United States Census
1902	1,708,720	Reports of United States Census
1911	3,188,541	Report of California Conservation Commission
1919	4,219,040	Reports of United States Census
1929	3,540,350	Reports of United States Census
1939	4,276,554	Reports of United States Census
1949	6,438,324	Reports of United States Census
Present (1950)	6,850,000	State-wide Water Resources Investigation

The ground waters of California have been extensively tapped for irrigation, as well as for domestic and municipal uses. Improvement of pumping equipment and extension of electric power service generally over most of the important ground water basins, together with the cited growth of water requirements, have so stimulated development that in some of these basins the ground waters have been overdrawn. Serious losses have already resulted and more will follow unless corrective measures are taken. Underground sources furnished about half of the domestic, municipal, industrial, and irrigation water in California in 1949.

Advances in the use of water in other fields have also been striking. Commercial hydroelectric power, first developed in California in 1893, constitutes approximately half of the presently installed power capacity in the State. Water supplies for municipalities, initially secured locally, are now in some cases being brought great distances. Outstanding illustrations are the aqueducts importing Sierra Nevada water to San Francisco and its environs, to the East Bay cities, and to Los Angeles, and the conduit bringing Colorado River water to Los Angeles and the other communities constituting the Metropolitan Water District of Southern California.

During the last 20 years federal agencies have entered the field of water resource development in California in a large way in the financing and construction of projects for water conservation, irrigation, navigation, and flood control, and for the protection of wildlife. Both the Corps of Engineers of the United States Army and the Bureau of Reclamation of the Department of the Interior have outlined comprehensive proposals, some of which have been authorized, with construction of several under way. The most extensive federal project now under construction is the Central Valley Project, which is being built in substantial accord with the State Water Plan, referred to later in this chapter.

Progress in the use of water in California has been made despite two incompatible doctrines governing rights to the use of water in surface streams, those of appropriative and of riparian rights. A similar conflict has been encountered in rules applicable to ground water, between the overlying right, formulated by analogy to the riparian right, and appropriation. Recognition of pueblo rights is based on terms of the treaty with Mexico when Alta California was acquired by the United States, but such rights are now exercised only by the Cities of Los Angeles and San Diego.

The appropriative doctrine in its generally accepted form originated in this State in the early mining customs. These were recognized by the courts, but the earliest statute sanctioning this doctrine was enacted on March 21, 1872. (Cal. Civ. Code, Secs. 1410-1422.) Prior to December 19, 1914, an appropriative water right could be established in California either by actual diversion and application of the water to beneficial use, or by posting a notice at the point of diversion and recording the notice with the county recorder, followed by diligence in construction and application of the water to beneficial use. Since that date an appropriative right to water, other than percolating ground water, must be initiated by filing an application with the Division of Water Resources of the State Department of Public Works, pursuant to Divisions 1 and 2 of the State Water Code (formerly the Water Commission Act). In contrast with either a riparian right to surface water or an overlying right to ground water, an appropriative right is created by use and is lost by nonuse.

The opposing riparian doctrine as now established in California consists of the old common law rule, as modified by California court decisions, and particularly by Section 3 of Article XIV of the State Constitution adopted in 1928, and decisions following and applying it. Under this doctrine, a riparian landowner is entitled to a reasonable use of water correlative with all other riparian owners bordering on the same stream, lake, or watercourse, except that all the water may be consumed by an upper riparian owner if necessary for domestic use. The State Supreme Court, in a line of decisions between 1886, Lux v. Haggin, and 1927, Herminghaus v. Southern California Edison Co., vacillated between strict application and liberalization of the old common law rule. The harsh construction of the rule in the latter case brought about a general demand for modification. The result was adoption of the constitutional amendment of 1928. This amendment, which has repeatedly been upheld by the courts of the State, imposed reasonable and beneficial use on riparian as well as on other water users. It provides as follows:

"Sec. 3. It is hereby declared that because of the conditions prevailing in this State the general welfare requires that the water resources of the State be put to beneficial use to the fullest extent of which they are capable, and that the waste or unreasonable use or unreasonable method of use of water be prevented, and that the conservation of such waters is to be exercised with a view to the reasonable and beneficial use thereof in the interest of the people and for the public welfare.

"The right to water or to the use or flow of water in or from any natural stream or water course in this State is and shall be limited to such water as shall be reasonably required for the beneficial use to be served, and such right does not and shall not extend to the waste or unreasonable use or unreasonable method of diversion of water. Riparian rights in a stream or water course attach to, but to no more than so much of the flow thereof as may be required or used consistently with this section, for the purposes for which such lands are, or may be made adaptable, in view of such reasonable and beneficial uses; provided, however, that nothing herein contained shall be construed as depriving any riparian owner of the reasonable use of water of the stream to which his land is riparian under reasonable methods of diversion and use, or of depriving any appropriator of water to which he is lawfully entitled. This section shall be self-executing, and the Legislature may also enact laws in the furtherance of the policy in this section contained."

In 1935 the Supreme Court of California in the case of Peabody v. City of Vallejo, 2 Cal. 2d 351, 40 P. 2d 486 (1935), fully approved and upheld the constitutional amendment, saying in part as follows:

"The limitations and prohibitions of the constitutional amendment now apply to every water right and every method of diversion. Epitomized, the amendment declares:

"1. The right to the use of water is limited to such water as shall be reasonably required for the beneficial use to be served.

"2. Such right does not extend to the waste of water.

"3. Such right does not extend to unreasonable use or unreasonable method of use or unreasonable method of diversion of water.

"4. Riparian rights attach to, but to no more than so much of the flow as may be required or used consistently with this section of the Constitution.

"The foregoing mandates are plain, they are positive, and admit of no exception. They apply to the use of all water, under whatever right the use may be enjoyed. The problem is to apply these rules in the varying circumstances of cases as they arise."

The new policy of water law was given its full expression in the case of Meridian Ltd. v. City and County of San Francisco, 13 Cal. 2d 424, 90 P. 2d 537, 91 P. 2d 105 (1939), wherein, for the first time, the court held in effect that (1) title to all unappropriated water over and above proper demands and requirements of vested rights is in the State in trust for the use and benefit of the people. It was also held that (2) it is for the State to prescribe the regulations pursuant to which rights to use such unappropriated water might be acquired. Further, it was held for the first time that (3) upstream storage in and of itself for flood control and stream flow stabilization for future use is a beneficial use of water. The court directly held that (4) the declarations in the Water Commission Act (now codified in the Water Code) of ownership of all unappropriated water by the State were implicit in the 1928 constitutional amendment, and are to be given full force and effect.

THE CALIFORNIA WATER PROBLEM

The over-all water problem of California is made up of many interrelated problems, some of which are mainly local, while others are state-wide in implication. Prior to the time when the southern part of California had to turn to the Colorado River, and until rapidly receding ground waters in southern San Joaquin Valley brought about initiation of the Central Valley Project, water needs were met in most instances by some form of local action. It is now generally realized, however, that a greater measure of state leadership and participation in planning and construction is required if the water resources of California are to be properly controlled, regulated, protected, and utilized to meet rapidly increasing needs of the people.

From a state-wide point of view, redistribution of the water supply from areas of surplus to areas of deficiency provides the greatest challenge. About two-thirds of the water is in the northern third of the State, whereas the greater requirements—agricultural, industrial, and municipal—are in the central and southern portions. The solution of such a geographical problem must involve transportation and exchange of water, generally from north to south. It must include construction of surface storage reservoirs and utilization of the great ground water storage capacity of the valleys for regulating stream flow. Multiple-purpose basin and transbasin developments will be required, involving many complex technical, financial, and legal problems. There must be increased development and transmission of hydroelectric energy for project purposes and to help meet growing urban and agricultural demands for electric power. Solution of the problems of flood control involves construction of detention reservoirs, levees, channel improvements, and by-pass channels. In many situations flood control and conservation works can be combined, but even where this is possible complete flood control may require additional separate works. In the Central Valley, conservation features will provide a substantial measure of salinity control, as well as improvements to navigation. On many if not most streams of the State, water conservation will contribute to recreation, fish, and wildlife, and other beneficial purposes.

A century of experience in California has demonstrated that growth and development of the State depend on the adequacy and economical utilization of its water supply. The California Water Plan will furnish a present pattern to meet the future need. It will enable the comprehensive and coordinated control, regulation, and utilization of this great and most vital resource, and will be susceptible of construction by stages as the need develops. However, as the future unfolds, as more and better information becomes available, and as conditions change, planning for water resource development must continue.

PREVIOUS INVESTIGATIONS

The first broad investigation of the irrigation problem of California was made by a board of commissioners on "The Irrigation of the San Joaquin, Tulare, and Sacramento Valleys of the State of California," described in a report published by the House of Representatives in 1874 as Ex. Doc. No. 290, Forty-third Congress, First Session. It outlined a hypothetical irrigation system for the San Joaquin, Tulare, and Sacramento Valleys. Other investigations by federal and state agencies followed during the next several decades, the most noteworthy of which were by Wm. Ham. Hall, State Engineer from 1878 to 1889. His reports contain meteorological and stream flow data, with notes on irrigation, drainage, and flood control, all of which proved of great value in planning water developments in the years that followed.

The most comprehensive recent investigations of the water resources of California were those by the State Engineer under authority of acts of the Legislature in 1921, 1925, and 1929. First reports of these investigations were presented in Division of Engineering and Irrigation Bulletins Nos. 4, 5, and 6, and in Division of Water Resources Bulletins Nos. 9, 12, 13, 14, and 20. A report giving results of subsequent investigations and outlining revised proposals was published in 1930 as Division of Water Resources Bulletin No. 25, entitled "Report to Legislature of 1931 on State Water Plan." It outlined a coordinated plan for conservation, development, and utilization of the water resources of California. The plan was approved and adopted by the Legislature by Chapter 1185, Statutes of 1941, and designated the "State Water Plan." The State Water Plan was amended by Chapter 329, Statutes of 1945, which eliminated the proposed Trinity River Diversion. Division of Water Resources Bulletins Nos. 26, 27, 28, 29, and 31 outlined in greater detail project plans for coordinated development of the water resources of the Central Valley, and for water conservation and flood control in the Santa Ana River Basin. Bulletins Nos. 34, 35, and 36 dealt with collateral matters of water charges and costs and rates of irrigation development. Bulletin No. 31 discussed briefly the plans for diversion and transmission of Colorado River water to the South Coastal Basin under the project of the Metropolitan Water District of Southern California.

OBJECTIVE OF STATE-WIDE WATER RESOURCES INVESTIGATION

Although investigations that led to the State Water Plan were conceived as comprehensive and state-wide, they were never completed in that pattern. All phases were not considered for certain areas of the State, and important projects were omitted and left for further study. Furthermore, although adopted by the Legislature in 1941, the plan was formulated in 1930 and was based on investigations and studies conducted in the preceding decade. Since 1930 the population of California has almost doubled, and the need for flood control, water conservation, and power has more than kept pace with population and industrial growth.

The objective of the current state-wide water resources investigation is, therefore, the preparation of The California Water Plan, a revised and more complete plan for the fullest conservation, control, protection, and utilization of the water resources of California, both surface and underground, to meet present and future water needs for all beneficial purposes and uses in all areas of the State, so far as is practicable.

SCOPE OF BULLETIN

As has been stated, this is the second in a series of bulletins concerned with preparation of The California Water Plan. The first of the series, "Water Resources of California," which was released by the State Water Resources Board in 1951, comprises an inventory of the water resources of the State. This present bulletin constitutes a determination of the present use of water throughout California and a forecast of the ultimate water requirement. These two publications provide many of the basic hydrologic data and information necessary for preparation of the third bulletin, which will describe The California Water Plan. A fourth bulletin will contain a summary of the earlier publications of the series.

A brief and generalized description of the methods employed in estimating the present use of water and forecasting the ultimate water requirement will serve to illustrate the scope of this bulletin. In general, the estimates and forecasts were made on an areal basis; that is, determinations were made by service areas of the various types of development making beneficial use of water. Appropriate factors of unit water use were then applied to these areas in order to estimate their total water requirement.

In the case of the present water requirement, areas of water-using urban and irrigated agricultural types of development, as determined from land use survey data, were multiplied by chosen factors of unit water use, and the products added to obtain the total water requirement. Data on unit use of water in metropolitan and urban areas were obtained generally from records furnished by water service agencies of deliveries to representative blocks of the various types of development. Data on unit use of water for irrigation were obtained generally from delivery records and from the results of experiments, and were modified to account for variations in climate and agricultural practice in the several parts of the State. Because of the importance of the three great metropolitan areas of California, in and around San Francisco, Los Angeles, and San Diego, relatively detailed land use surveys and determinations of unit use of water were conducted in these areas.

In the case of ultimate water requirement, the entire area of the State was considered. The inherent capacity of the land to support the various types of development requiring water service was determined as follows:

1. Urban land use was projected on the basis of indicated trends of growth and development, communications, natural resources, and other factors pertinent to a balanced economy.

2. Irrigated agriculture was projected on the basis of land classification survey data, on the assumption that all irrigable lands not presently served with water will ultimately receive a complete and adequate water supply.

3. Remaining lands of the State, neither urban in character nor given over to irrigated agriculture under ultimate conditions of development, were projected on the assumption that they will support a rural population, generally sparse and widely scattered but requiring a water supply for sustenance.

To the ultimate pattern of land use so determined—urban, irrigated agricultural, and other water service areas—appropriate factors of unit water use were applied, and the products added to obtain the forecast of ultimate water requirement. The unit water use factors for irrigated agriculture were generally the same as those used in connection with the present land use pattern, but the factors for urban use were modified in accordance with indicated trends. Few data were available regarding unit use of water by the types of development in remaining lands of the State, and factors of unit water use adopted were necessarily based on limited information as to present deliveries of water.

Dependent upon local conditions, either all or a portion of the water served to the foregoing urban, irrigated agricultural, and other water service areas is consumed or lost to further beneficial use. However, there are other uses of water that are not necessarily consumptive in their nature, such as those for the generation of hydroelectric energy, for the propagation and preservation of fish life, and for recreation. Furthermore, certain factors of demand may be imposed upon the water by the nature of its beneficial use, such as those pertaining to specific rates, times, and places of delivery of the water, losses of water, and quality of the water. In general, these nonconsumptive uses and demand factors incidental to water service can only be evaluated on the basis of a specific plan of water resource development. For purposes of this bulletin, therefore, they are discussed in general terms with particular regard to their effects on The California Water Plan, in which plan they will necessarily be given more detailed consideration.

Since a principal purpose of studies leading to preparation of this bulletin was to provide information required in preparation of The California Water Plan, it was necessary to compare the present yields of water supply works with the present water requirements. Any resulting estimates of deficiency under present conditions were then added to the difference between estimated present and utimate water requirements in order to determine the probable ultimate supplemental water requirements. This served to establish the approximate general pattern of required future regulation and conveyance of water throughout California. However, the exact pattern will be dependent upon the feasibility and relative costs of alternative works, studies of which are under way in connection with preparation of the next bulletin in this series.

The following chapter describes in some detail the methods and procedures used in the estimates and forecasts of water utilization and requirement. It is followed by separate chapters for each of the seven major hydrographic areas of California, in each instance presenting and discussing the estimates and forecasts for the respective hydrographic areas and subdivisions thereof. These chapters also contain descriptions of the hydrographic areas and their subdivisions, water supply conditions and development, and land use as it relates to water utilization and requirement. A final chapter summarizes on a state-wide basis the material presented in earlier portions of the bulletin.

Doctor David Weeks, Professor of Agricultural Economics at the University of California in Berkeley, and an authority on agricultural economics and trends, conducted the studies reported in this bulletin dealing with the probable crop pattern in California under conditions of complete development. His paper on this subject is included as Appendix A.

Appendix B comprises a list of water service agencies in California. Insofar as could be determined within the scope of the investigation, the list constitutes a complete compilation of all known public and private agencies presently supplying water for domestic, municipal, or irrigation purposes in the State.

GENERAL CONSIDERATIONS RELATING TO WATER UTILIZATION IN CALIFORNIA

The State Water Resources Act of 1945, the basic law under which this bulletin was prepared, states in part as follows:

> "In studying water development projects, full consideration shall be given to all beneficial uses of the State's water resources, including irrigation, generation of electric energy, municipal and industrial consumption of water and power, repulsion of salt water, preservation and development of fish and wildlife resources, and recreational facilties, but not excluding other beneficial uses of water, in order that recommendations may be made as to the feasibility of such projects and for the method of financing feasible projects. Fish and wildlife values, both economic and recreational, shall be given consideration in any flood control or water conservation program."

As a preface to the ensuing presentation of data and estimates, it is considered desirable to discuss in general terms certain aspects of water utilization in California in the light of the foregoing directive of the Legislature. This section, then, comprises a brief description and discussion of the major beneficial uses of water in the State, their interrelationships, their demands upon the available water resources, the indicated trends in such uses of water, and related factors such as costs of water. The prefatory statement should facilitate understanding of the subject matter of this bulletin.

Water Supply

It was shown in Bulletin No. 1, "Water Resources of California," that the total runoff of all streams of the State, measured as they enter valley and mesa lands, averaged nearly 71,000,000 acre-feet per season over the 53-year mean period from 1894-95 through 1946-47. In addition, precipitation in the mean seasonal amount of over 32,000,000 acre-feet fell on valley and mesa lands during the 50-year period from 1897-98 through 1946-47, of which a portion was available to meet demands on the water resources of the State. When the available water resource is compared with the estimated present total mean seasonal water requirement of the State of about 25,000,000 acre-feet, measured in terms of consumptive use of applied water plus irrecoverable losses, and the forecast ultimate requirement of about 51,000,000 acre-feet, as presented later in this bulletin, this water resource might seem to be generously ample. However, as regards both location and time of occurrence, the fresh waters of California are not well related to the demands put upon them. For these reasons, it is probable that they will be only partially conserved and put to beneficial use even under conditions of ultimate development.

Nearly 28,900,000 acre-feet, or about 41 per cent of the total mean seasonal runoff of California, occurs in the North Coastal Area, and about 22,400,000 acre-feet, or nearly 32 per cent of the State's total, in the Sacramento River Basin of the Central Valley Area. Thus, over 72 per cent of the runoff occurs north of a line drawn roughly through Sacramento. In unfortunate contrast, an estimated 77 per cent of the present water requirement of the State occurs south of the same line, which value is expected to expand to about 80 per cent under conditions of ultimate development. From this it is apparent that solution to the basic water problem of California must involve the transportation of substantial amounts of water from north to south.

Both precipitation and runoff in California vary widely in their occurrence within the season and from season to season. Generally, precipitation is confined to winter months, and summers are extremely dry. The amount of flow in streams follows closely the occurrence of precipitation, and in many streams the flow dwindles to nothing in summer and fall. This characteristic of runoff is modified somewhat in streams of the Sierra Nevada, wherein high stream flow may be sustained well into summer by the storage effect of heavy snowpack in the mountains.

Aside from monthly variation in her natural water supply, California is subject to wet and dry periods during which average precipitation and runoff depart far from the mean. The periods may extend for many years. One of the most severe dry periods in most of the State extended from 1928 through 1934. A severe drought was experienced in the southern part of California from 1895 through 1904. More recently, and following a very wet period from 1938 through 1944, the State suffered dry seasons from 1945 until 1952, which latter season was exceptionally wet. Generally in California the seasons of 1923-24 and 1930-31 were the driest of record. In 1923-24 the estimated total runoff to valley and mesa lands was only about 18,300,000 acre-feet. Maximum seasonal runoff during the period of record occurred in 1937-38 and is estimated to have been about 135,000,000 acre-feet. During the critical 10 years from 1927-28 through 1936-37, average seasonal runoff was 69 per cent of the 53-year mean, and during each season of that drought period runoff was less than the mean.

Severe and damaging floods are another symptom of the erratic occurrence of California's water resources. Ever since the first settlements on flat lands along the banks of streams, periodic floods have endangered life and property. Most floods of the State are of two general types, with quite different characteristics. Rainwater floods occur in winter months and are caused by protracted general storms affecting wide areas. On rare occasions peak discharges of such floods are extremely high, but the flood duration is short, usually no more than a few days. Snow floods, resulting from rapid melting of the snowpack, occur in streams that drain the higher mountains of the State, principally the Sierra Nevada. Characteristically, such floods occur during months from April through July, and have much longer duration and lower peak flow than rainwater floods.

Maldistribution of the water resources of California, as regards both place and time of occurrence, has made necessary the construction and operation of numerous works to control and regulate the flow of streams, convey the conserved water to areas of use, and distribute it therein. California has long been a leader in the development of outstanding hydraulic works, a major portion of which have been financed, constructed, and operated by local public and private agencies. If the State is to realize her full potential, additional works of even more imposing size and scope must be achieved to control, regulate, distribute, and permit the required utilization of her bountiful water resources.

The extensive ground water basins of California provide natural regulation for runoff from tributary drainage areas and for precipitation directly on the overlying lands. As has been stated, more than half of the water presently used on irrigated lands and for domestic, municipal, and industrial purposes in the State is regulated in ground water basins. Additional natural regulation would be provided if presently unused ground water storage capacity were utilized to the full extent of possible safe yield of the basins. Furthermore, as additional surface water supplies are developed and made available for storage in ground water basins, safe yield of the underground reservoirs will be increased. Under ultimate development the maximum amount of water could be made available on demand through operation of surface reservoirs in conjunction with cyclic underground storage. Such coordinated operation would necessitate an adequate supply of energy to pump ground water in a series of dry years. The extent of the valley fill areas of California is indicated on Plate 4, "Valley Fill Areas." Many of these are known ground water basins, whereas the susceptibility of some to ground water storage remains to be established.

Most fresh waters in California are of excellent quality and well suited to irrigation and other beneficial uses. This is especially true of drainage from the North Coastal Area and from the eastern side of the Central Valley Area, both of which areas have large watersheds with high water yield. Analyses show that their surface and underground waters possess remarkably slight concentrations of salts, low per cent sodium, and relatively small amounts of elemental boron. These waters are of the bicarbonate type, and calcium is the predominating base. Surface waters of comparatively high salinity are found in streams on the west side of the San Joaquin Valley, in Cache Creek in the Sacramento Valley, in basins on the west slope of the Diablo Range that separates the Central Coastal and Central Valley Areas, in Cuyama and Santa Maria Rivers in the Central Coastal Area, and in Piru and Sespe Creeks in the South Coastal Area. Mineral solubles in these waters include significant amounts of boron, and relatively high concentrations of sulphates or chlorides. Ground waters receiving replenishment from such inferior surface waters have similar chemical characteristics.

Gradations in the quality of fresh water supplies of California are mainly correlated with climate, soil, and geologic complex. Any significant variation in chemical properties not correlated with these natural factors is usually caused by pollution or contamination from foreign sources. These may include industrial wastes and sewage, unconsumed irrigation water, or imported water of inferior quality. Depreciation in quality of ground water may also result from infiltration of sea water along the coastal strip, from defective wells, and from lack of salt balance due to inadequate ground water outflow.

Irrigation

Most of the arable lands of California are situated in regions classified climatically as arid or semiarid, where rainfall is generally insufficient to support the growth of perennial crops. For this reason, and because of the characteristically long rainless summers even in well-watered regions of the State, irrigation is extensively resorted to in order to make agricultural enterprises possible or more profitable. For many years California has led all states of the Union in irrigated agriculture, and, as has been stated, some 7,000,000 acres within the State are served with irrigation water. This constitutes by far the greatest single demand on the developed water supplies of California, and about 90 per cent of the water beneficially used in the State is utilized by irrigated agriculture.

Agricultural crops utilize varying amounts of the rain that falls upon them. Certain perennial crops, such as alfalfa and irrigated pasture, continue to grow throughout the winter rainy season in most parts of California, and consume a portion of the precipitation to sustain this growth. On other agricultural lands where crops are not grown in winter there is some consumption of winter rainfall by evaporation from the bare land and by the growth of weeds and native grasses. Of the precipitation that percolates into the soil, a part may remain within the root zone of the plants for a considerable time and sustain their growth until exhausted. However, as has been stated, precipitation available to crops is not generally sufficient in California to meet their requirements throughout the summer. This deficiency can only be remedied by the application of irrigation water from developed sources. Monthly irrigation demands vary considerably, depending upon the type of crop, climate, and agricultural practice. On the average, little irrigation water is applied in winter months, and peak summer monthly demands may be as large as 25 per cent of the seasonal total.

√Ordinarily, a substantial portion of the irrigation water applied to his fields by a farmer is consumptively used by transpiration from the vegetative growth and by evaporation. However, the remainder of the applied water either percolates below the root zone of the crop or drains away on the surface, or both. The ratio of consumptive use of the applied irrigation water to the total amount of such applied water is termed "irrigation efficiency" and is employed as a rough measure of the relative efficiency of irrigation practices. Irrigation efficiency varies widely throughout California, depending on one or more of many factors, including the type of crop, topography, porosity of soil and subsoil, salinity of soil and water, method of irrigation, availability of water, and cost of water.

In areas of deficient water supply and high cost of water the tendency has been to restrict crops to those requiring a minimum amount of water. In certain parts of the South Coastal Area where such conditions prevail, farmers have restricted their application of irrigation water to less than the optimum amount which the plants could consume. This subnormal irrigation may have resulted in high irrigation efficiencies, but probably has reduced crop production in some cases. In parts of the Sacramento Valley water is relatively cheap and plentiful, and low irrigation efficiencies are common. Similar conditions usually hold in the Imperial Valley, but in this valley there is an urgent demand for excess irrigation water to flush detrimental salts from the soil. Generally throughout California irrigation efficiency probably averages between 50 and 60 per cent.

Since more water is applied for irrigation than is actually consumed by the plants, an opportunity exists for saving of water through its more careful application. In this connection a recent quotation by Dr. Frank J. Veihmeyer, former Chairman of the Irrigation Department of the College of Agriculture, University of California, is pertinent:

> "Deterioration of land due to wasteful use of water is prominent throughout the world. The belief that for the best condition of plants the soil should be kept wet is not founded on fact. You do not increase growth by maintaining large amounts of water in the soil. You can save water by reducing the number of applications. The irrigated area of California could almost be doubled, if waste could be avoided."

Careful application of irrigation water is infrequently obtained except in periods of drought emergency. In certain past studies of proposed irrigation works in the State it has been assumed that irrigated lands can withstand a deficiency of 35 per cent of the average seasonal requirement in seasons of critically deficient water supply, provided that these deficiencies do not occur frequently and in no case in consecutive seasons. This assumption is based on experience throughout California. In actual operation of several large irrigation systems, deficiencies of as large as 50 per cent of the requirement occurred in such extremely dry seasons as 1924 and 1931. In these instances permanent crops suffered no lasting damage.

In addition to losses of water inherent in its field application, in any water supply and distribution system a portion of the available water is lost by seepage and evaporation from reservoirs, leakage from conduits, seepage from canals, etc. The amount of these losses varies over wide limits. The principal factors affecting reservoir losses are the climate, permeability of the materials underlying the reservoir, area-depth relationship of the reservoirs, and design and maintenance of the impounding structures. Evaporation losses from reservoir surfaces average from three to four feet of depth per season in California, but may be as high as six or seven feet in dry, hot, windswept localities. Conveyance losses of water are generally dependent upon design and maintenance of the system, which in turn are largely influenced by economic considerations. In well-constructed and adequately maintained, closed-type conduits they may be negligible. In open, unlined ditch systems they may run higher than 50 per cent of the diverted water supply. Depending upon soil and geologic conditions, a portion of storage and conveyance losses may be salvaged for re-use. However, in many instances water lost in such fashion creates high water table conditions, damaging to crop lands.

Since 1940 there has been a marked acceleration in the placing of new lands under irrigation in California. This has been caused by increased requirements for agricultural produce brought on by World War II, by similar demands of the rapidly growing population of the State, and by sustained high farm prices. How long the present rate of growth of irrigated agriculture will continue is problematical. However, the eventual need for a very high degree of development of the irrigable lands of California seems assured. In studies for this bulletin it was assumed that under conditions of ultimate development all lands suitable for irrigated agriculture will be irrigated. It is realized that this complete irrigation development may not actually occur, and that in some areas it may always be more profitable to grow dry-farmed rather than irrigated crops on lands classified as irrigable. However, the assumption is conservative in the sense that it results in an estimate of maximum probable requirement for water. With this in mind, any lesser future requirement will be provided for in allocation of the available water resources of the State.

Urban Use of Water

The people living in the urban centers of California and the commerce and industry that serve and support them create a demand on the developed water supplies second only to that of irrigated agriculture. In meeting this requirement local public agencies of the great metropolitan areas of the State have constructed monumental engineering works exemplified by the Hetch Hetchy, Mokelumne River, Owens Valley, and Colorado River Aqueducts. Other urban communities of the State are served with municipal types of water supply from many sources, by both publicly and privately owned utilities.

Just as irrigated lands utilize precipitation, urban areas consume a portion of the rain that falls upon them. Home gardens, lawns, and parks are similar to irrigated crops in this respect, and there is also appreciable consumption of rainfall by evaporation from impervious areas, such as roofs, walks, and streets. In addition, urban areas consume portions of the water supplies delivered to them from artificial sources. The monthly urban demand on such water supply sources differs from that for irrigation because it is more uniform throughout the year, the use of water for domestic, commercial, and industrial purposes being relatively constant. On the average, monthly urban demands for water in the winter vary from 5 to 6 per cent of the seasonal total, while monthly summer demands vary from 10 to 15 per cent of this total.

Of the several classes of water use comprising the urban requirement, that of the commercial type of development may be the greatest on the basis of unit area, but the areal extent of commercial enterprise is usually less than five per cent of the whole community. Industrial requirements vary between wide limits from industry to industry, and even within industries of the same type. Industrial use of water in the metropolitan type of community in California is usually a substantial part of the total requirement, and varies from about 10 per cent to more than a third of the total. However, the various classes of residential use normally comprise the greatest single demand on urban water supplies.

The water supplied to meet urban requirements is not all consumptively used. Portions may run off on the surface or percolate to underlying ground water basins. A substantial portion is discharged to the sewers, and, depending upon the means of sewage disposal and its mineral and bacteriological quality, may or may not become available for re-use. The amount of sewage from urban communities in California varies from about 25 to 75 per cent of the amount of water delivered to them, and probably averages about 50 per cent throughout the State. Reclamation of water from sewage as a source of water supply is accomplished in many interior communities incidental to return of the water to ground water basins or stream channels. Construction of works for sewage reclamation is receiving consideration in several coastal communities with present water shortages, and may become a more important part of water conservation development in the future.

In studies being made in connection with preparation of The California Water Plan, it is being assumed that no deficiency in urban water supply will be permitted, and that the requirement will be fully met at all times. This is a most conservative assumption, for it has been frequently demonstrated in California that in times of drought emergency it is possible to decrease urban water use very materially without undue hardship. This has been accomplished by enforced rationing and by educational campaigns to avoid unnecessary waste. In one community, as a result of serious shortage in water supply caused by a series of exceptionally dry years, the amount of water delivered in 1948 was reduced 26.3 per cent below that delivered in 1947. This was accomplished by enforced rationing and education. In another city the use of water was reduced from 64 million gallons on one day to 38.5 million gallons on the ensuing day by means of a newspaper and radio educational campaign.

Historically, the population growth of California has been rapid but intermittent. Certain communities have nearly doubled their population each decade since 1900, and throughout the State the population increased 53 per cent from 1940 to 1950. Perhaps the most significant recent trend in urban growth in California is toward decentralization of residential and commercial types of development in fringe areas around the existing communities. In studies for this bulletin, probable ultimate urban use of water was forecast generally on the assumption of an ultimate population approximately four times as great as at the present. This ratio was based on results of detailed studies of complete land use and of population saturation in the San Francisco Bay, Los Angeles, and San Diego metropolitan areas. It is believed to be reasonably conservative in the aggregate, although probably subject to wide error in particular instances.

Hydroelectric Power

A large and important nonconsumptive demand on the water resources of California is that imposed by use of water for generation of hydroelectric energy. Of recent years the requirement for electric power has increased even more rapidly than population. The total amount of power generated for use in California in 1940 was a little over 13 billion kilowatt-hours, of which about 3.3 billion were from plants located on the Colorado River outside of the State. In 1950 the total was more than 29.6 billion kilowatt-hours, an increase of some 127 per cent. Of the total, about 4.8 billion kilowatt-hours came from Colorado River plants. Locations of the principal power installations of the State, both hydroelectric and fuel-electric, transmission lines, and substations, are shown on Plate 5, "Electric Power Development, 1954."

In order to meet the rapidly growing requirement for electric power it has been necessary for electric utilities in California to increase their capacity materially, particularly since World War II. For various reasons, principally economic in nature, the greater part of this increase has been made by construction of fuel-electric plants rather than hydroelectric. However, even today the total installed capacity of hydroelectric power plants in California is approximately one-half that of the total of all types of electric power generating plants. In 1940 the installed capacity of all electric plants within the State totaled about 2,720,000 kilowatts, of which approximately 1,540,000 kilowatts were hydroelectric installations and the remainder fuel. In 1950 the total installed capacity was about 5,320,000 kilowatts, of which approximately 2,600,000 kilowatts were hydroelectric. It is believed to be reasonably safe to assume that with probable continued rapid population and industrial growth of California, and with the demonstrated trend for even more rapid increase in requirement for electric power, a demand will exist in the future for all hydroelectric power that can be obtained from further development of the water resources of the State.

In order to be capable of producing large amounts of firm energy, that is, energy available on demand, a hydroelectric power plant requires an abundant, nearly uniform supply of water located at high elevations to provide large potential fall. These desirable conditions occur only in rare instances in California. Although relatively large watersheds have sufficient elevation to provide substantial fall, many such areas, particularly in the southern part of the State, have so limited or intermittent a water supply that development of hydroelectric power is impracticable. In the Sierra Nevada, and more particularly in the northern Sierra, topography and water supply conditions are more nearly ideal for hydroelectric energy generation. By far the greatest development of hydroelectric power in California has been in the Sierra Nevada, and present development is continuing in this area. In the northwestern portion of the State the water supply is ample but the topographic relief is not as great as in the Sierra, and a relatively large part of the water originates at low elevations. Nevertheless, the potential for hydroelectric power development in the North Coastal Area is very large. Only minor installations have been constructed in this area to date.

Because of the characteristic seasonal nature of the water supply throughout California, regulatory storage is almost always necessary for the production of firm energy throughout the year. Due to the extreme variation in flow of most streams, it is usually necessary to generate large amounts of secondary energy in order to utilize the development to its economic potential. This makes desirable the full coordination of power generation from hydroelectric sources with that from fuel-electric sources. The demands on the water supply for power purposes coincide only in part with those for other beneficial uses of the water, such as irrigation, and can be only partly coordinated with them. To offset the effects of this incompatibility, revenues from the sale of hydroelectric power from multipurpose projects have served in many instances to make irrigation and other features of the projects financially feasible.

Without consideration of economic or engineering feasibility, or of conflicts with other demands on the water supply, it is estimated on a theoretical basis that the presently developed and potential undeveloped hydroelectric power capacity within California is of the order of 10,700,000 kilowatts. Approximately 4,000,000 kilowatts of this capacity occurs in streams of the Sacramento Valley, 3,200,000 kilowatts in those of the San Joaquin Valley, and 600,000 kilowatts in the Lahontan and Colorado Desert Areas, while the remaining capacity, some 2,900,000 kilowatts, occurs in the North Coastal Area. Only minor possibilities for future hydroelectric power installations exist elsewhere in the State.

Timber and Minerals

The natural resources of California support an important group of basic industries, of which oil and gas, timber, and the mining industries occupy the more prominent positions. Significant use of water by the oil and gas industry is confined to refining and processing, and is considered in this bulletin along with urban requirements. Use of water by the timber and mining industries is an item of importance in local areas in which the industries are located, although the total use for this purpose is minor in comparison with other consumptive uses of water in the State. The locations of principal timber lands and auriferous gravel deposits are shown on Plate 6, "Timber Lands and Auriferous Gravel Deposits." Data for this plate were furnished by the United States Forest Service and the State Division of Mines.

Commercial stands of timber are found principally in the mountainous parts of the North Coastal Area and above 3,000 feet on the westerly slopes of the Sierra Nevada in the Central Valley Area. Less important stands of commercial timber occur along the easterly slope of the Coast Range in the Central Valley Area, in Santa Cruz and San Mateo Counties, and in the Lahontan Area between Mono and Lassen Counties. A few comparatively small stands of timber are located in the southerly part of the State.

The timber cut in California amounted to about 5.7 billion board feet, International Scale, in 1952. The estimated requirements for production of lumber and timber by-products are about 56,000 gallons of water per 1,000 board feet for pulp production, 2,300 gallons per 1,000 board feet for fiberboard, and 1,000 gallons per 1,000 board feet for lumber products. On this basis the consumptive use of water in the timber industry in 1952 was about 311,000 acre-feet.

The present growth on some 16,000,000 acres of timber lands susceptible of commercial development in California is estimated to be about 1,200,000,000 board feet per year. It is forecast that, under ultimate conditions and with adequate crop management, an annual yield of 3,800,000,000 board feet is possible. The water requirement for processing this sustained timber yield will be about 232,000 acre-feet per year.

Discovery of gold at Coloma by James W. Marshall in 1848 caused the initial influx of white men which led to permanent settlement and development of California. The present large mining industry, which includes the extraction and processing of numerous valuable metallic and nonmetallic minerals, including sand, gravel, and building stone, has grown from the meager beginning at Coloma. Among the valuable minerals found in this State, gold has always occupied a principal place in the imagination of mankind, and the profusion in distribution of gold has maintained it in a leading position in California's mining industry. Much of California's gold production results from the mining of placer deposits, where gold is found in nugget or granular form. Gold is extracted from placer deposits, also known as auriferous gravels, by hydraulic methods, including the washing of gravels from hillsides by the use of jetted streams of water under high pressure and by dredging.

The production of gold in California in 1952 was about 258,000 ounces, much of it from the gravel deposits. Available estimates of the water required for production by hydraulic methods range from 1.25 to 1.5 acre-feet per ounce of gold. Very little of this water is used consumptively, the greater portion being returned to stream channels where it is available for re-use.

Past methods of operation in hydraulic mining areas have resulted in the discharge of large quantities of mining debris, consisting of sand, gravel, soil, and vegetable matter, into the stream channels in placer areas, and the deposition of sand and gravel waste in dredging areas. The California Debris Commission has constructed several dams for the sole purpose of retaining placer waste and preventing such material from adversely affecting productive valley floor agricultural lands. Space in reservoirs constructed for other purposes has also been made available for debris collection through mutual arrangements between mine operators and the agencies controlling the reservoir areas. The restrictions now placed on hydraulic mining and dredging to prevent stream pollution and destruction of land indicate that in the future gold will be produced by less destructive methods and that smaller amounts of water will be required.

Reduction, concentration, and refining of ores require a relatively small consumptive use of water in relation to the volume of the final product. The different processes used require varying amounts of water, but the total requirement, most of which is returned to stream chanels and underground basins and is available for re-use, is relatively minor. Much usage of this nature, particularly the requirement for final refining, is combined with general industrial requirements in urban and suburban water service areas.

Recreation and Fish and Wildlife

By virtue of her climatic advantages and wide variety of natural attractions, California enjoys an outdoor recreational opportunity of significant importance to her growth and economy. With anticipated continued growth in population of the State, it is expected that the public demand for preservation and enhancement of recreational facilities will be sufficient to assure the provision of water supplies necessary for such purposes. The principal recreational facilities of the State are indicated on Plate 7, "Recreational Areas."

In the aggregate the amount of water used for domestic and service facilities in recreational areas of California is relatively small, and the demands are widely scattered. As for waters employed for boating, sailing, swimming, and other water sports, most are available naturally or as a result of works constructed and operated for other purposes, and the nonconsumptive recreational use of the water is incidental to other uses. The flow of streams and the water in lakes and ponds that enhance the esthetic value of recreational areas rarely have been supplied primarily for recreational purposes. In only a few instances, principally in national parks and monuments, have such recreational water requirements been considered equal or superior to those for other beneficial purposes. Among the many uses of water for recreational purposes in California, those associated with the preservation and propagation of fish and wildlife are probably the most substantial. In this connection, certain species of fish propagated in fresh-water streams of the State support an important offshore commercial fishery.

The principal present consumptive use of water in California related to fish and wildlife is the water utilized to maintain ponds and feeding areas for migratory wild fowl. Data collected in connection with the current investigation indicate that about 100,000 acres of fresh-water ponds for wild fowl are presently maintained throughout the State. The seasonal delivery of water to these ponds totals some 400,000 acre-feet, most of which is consumptively used. The wild fowl ponds are included in state and federal waterfowl refuge and management areas, and in commercial and private gun clubs. They are located principally in the Central Valley Area, although some are scattered throughout the State. In addition to the ponds, a nearly equal area of adjacent land is irrigated and cropped to feed migratory waterfowl, with a requirement for water nearly as great as for the ponds.

Both the United States Fish and Wildlife Service and the California Department of Fish and Game foresee the future provision of additional facilities for migratory wild fowl. Based largely on studies by these agencies, it is indicated that some 190,000 acres will eventually be used for wild fowl ponds, with a seasonal application of water of nearly 650,000 acre-feet. With regard to future use of land and water for this purpose, the following is quoted from a recent statement of the Department of Fish and Game:

> "It is in the needs of water for waterfowl and other game species requiring wet lands for their existence that man's agricultural and economic water needs have made the greatest inroads. Vast acreages of former marsh or semi-marsh lands have been drained for farming or other purposes, pushing these species into a small existing area which in turn is further subject to demands for more land and more water. Waterfowl are vitally dependent on free water over productive land areas. Their continued existence depends on planned reservation of water for their use. Other minor aquatic wildlife species, such as shorebirds, muskrat, beaver, etc., will benefit from any planning for waterfowl.
>
> "In order to allocate water for these species, such allocation must be done for specific areas of the State, since waterfowl have definite habits and needs for certain types of lands and feeds which cannot be met with alternate situations. In other words, wintering grounds for waterfowl must be met in warm valley areas capable of growing good reliable foods. They cannot be met on mountain areas, or on areas of poor winter climate or inferior soil. Farming development has taken over the vast majority of lands formerly available to these species; the needs found below are allocated to lands that remain available in some measure for waterfowl. Provision must be made with as much speed as possible to see that not only lands, but water for these lands are devoted to waterfowl.
>
> "That California has in this matter an obligation not only to her sister States of the Pacific Waterfowl Flyway, but to our neighboring Nations to the North and South, has been brought out by many waterfowl authorities. This State has been the traditional wintering ground for vast numbers of birds of the Pacific Flyway. It has assumed this position of responsibility to the birds, if such it may be called, by virtue of its valley areas and their attendant winter climates. There is no substitute which will serve if these birds are to survive."

As in the case of water sports, few artificial lakes are utilized exclusively for fishlife in California, such use normally being incidental to the primary purposes for which the reservoirs were constructed. From some reservoirs, however, releases are made to maintain downstream flow conditions favorable to the preservation and propagation of fishlife. It is considered probable that in the future more reservoir storage capacity will be allocated to this purpose, and that some reservoirs will be constructed primarily to augment naturally low summer and fall stream flows in the interest of fishing.

Water released down a stream to maintain the minimum flow required for fishlife does not constitute a consumptive use of the water. The demands of fishlife, however, are frequently incompatible with hydroelectric power development and diversion for other beneficial uses of the water. Furthermore, in coastal streams of California, the migrations of anadromous fish such as steelhead, salmon, and striped bass can only be maintained by outflow of fresh water to the ocean in substantial amounts. Resolution of the inherent conflicts between the interests of stream fishing, and those of domestic, irrigation, hydroelectric power, and other requirements for water, is a problem for the future. It is believed that in many instances fishing must give way to the higher uses of water. However, an improved stream fishery can be developed and maintained by the dedication of certain streams, and certain reaches of other streams, to recreation and fishing, and by the construction of upstream storage to improve low stream flow conditions. In addition, reservoirs constructed to regulate stream flow for other purposes will provide a greatly increased lake fishery.

Repulsion of Sea Water

Insofar as the surface water resources of California are concerned, the repulsion of sea water has been a serious problem only in the delta of the Sacramento and San Joaquin Rivers. The low delta lands, reclaimed and protected by levees, are irrigated with water from adjacent fresh-water channels and sloughs. They include more than 350,000 acres of the most fertile and productive agricultural lands in the State. In the past, during years of low stream flow, and most notably in 1924 and 1931, saline water from upper San Francisco Bay moved far into the delta channels under the influence of tidal action. These saline invasions caused extensive damage to crops and farm lands, and resulted in marked depreciation of land values. After intensive study by the Division of Water Resources and others, it was concluded that control and prevention of the sea-water invasion could be most economically effected by repelling the saline water with fresh water released from upstream reservoirs. This was provided for in plans for the Central Valley Project. Operation of Shasta Reservoir started in 1941, and since then there has been no significant invasion of sea water into the Sacramento-San Joaquin Delta. Originally it was estimated that minimum outflows of about 3,300 second-feet would have to be maintained in the Delta to repel sea water. This estimate has since been increased to about 4,500 second-feet, of which 3,300 second-feet is measured inflow, and the remainder is unmeasured accretions in the Delta. This demand on the developed water supply is largely coordinated with reservoir releases for navigation, hydroelectric energy production, and other beneficial uses of the water.

So far as the ground water resources of California are concerned, the repulsion of sea water is a serious problem in many economically important ground water basins adjacent to the coast. Characteristically, these coastal basins are capped with impervious strata for some distance inshore, and the underlying confining aquifers connect with the ocean. The water in the aquifers moves under pressure caused by the difference in head between inland intake areas and areas of discharge from the aquifers. As a result of pumping from the aquifers, the hydraulic gradient, or elevation of the pressure head, may be lowered below sea level. This induces landward flow of sea water in the aquifers and saline degradation of the water supply. Heavily pumped ground water basins in the San Francisco Bay, Central Coastal, and South Coastal Areas have experienced such sea-water intrusion, which has forced abandonment of wells, and in some instances threatens permanent damage to the basins. Other coastal basins are susceptible to similar damage if pumping increases.

Experiments and studies have recently been conducted under direction of the State Water Resources Board to determine feasible methods of preventing sea-water intrusion of ground water basins. The experiments included the creation of a fresh-water mound in the confined aquifers, adjacent and parallel to the coast, by injection of fresh water in wells. The installation of various types of impervious membranes or dikes was also studied. In general, sea-water intrusion of ground water basins is a symptom of overdraft on the aquifers. In most cases the solution of the problem will probably involve the reduction of pumping draft on the aquifers, and the provision of a supplemental water supply from some other source. Basically, this solution is similar to that presently employed for surface waters of the Sacramento-San Joaquin Delta, that is, it involves repulsion of the sea water by fresh water.

Flood Control

Destruction and havoc caused by floods in California have frequently been accompanied by the economic anomaly of wastage of huge amounts of water into the ocean in areas of deficient water supply. Storage of such flood waters in upstream reservoirs would have accomplished the dual purpose of conservation of needed water and reduction of flood damages. However, storage capacity sufficient to contain all flood waters would require extremely large and expensive reservoirs. Generally in the past it has not been feasible to attain complete conservation and flood control by storage. Improvement of stream channels to provide capacities sufficient to contain peak flood flows, either separately or in combination with upstream storage, has usually provided the most economic solution to the problem of flood control in California.

The construction of works to control floods and reduce flood damage has been diligently pursued since the early days of California's statehood in the 1850's. One notable achievement is the Sacramento River Flood Control Project. This consists of an extensive system of leveed channels, by-passes and drainage pumps, to protect the fertile lands and cities of the Sacramento Valley. The project is operated by the State of California, and construction expenditures to date have totaled about $136,000,000. The funds have been provided nearly equally by local, state, and federal agencies. Another example of major importance is the flood control project in Los Angeles County.

This is a complex system of debris basins, detention reservoirs, and improved channels to protect the tremendous urban development in and around Los Angeles, and is only partially completed at this time. Expenditures to date are more than $225,000,000, and the funds have been provided by local, state, and federal governments. Los Angeles County has also recently voted a bond issue of $179,000,000 to construct a system of works for drainage of storm waters. These are but major examples of the many such projects throughout California. Over 700 reservoirs in the State, some of which are operated wholly or partially for flood control, impound flood waters and enhance the value of downstream channel improvements. However, in relatively few localities has complete or even reasonably adequate flood control been achieved. With expected continued growth of the State, a much higher degree of flood control must be provided to protect life and property.

Results of the State-wide Water Resources Investigation to date indicate that if California is to attain growth and development commensurate with her manifold resources, nearly all of the potential reservoir storage capacity of the State must be constructed and dedicated to operation for water conservation purposes. This in itself will result in a substantial increase in downstream flood protection. However, any portion of the available reservoir storage capacity that is operated wholly or partially for solely flood control purposes will correspondingly reduce the capacity available for conservation. Flood control operation requires the release of stored flood waters immediately upon expiration of the flood at rates within downstream channel capacities. Such operation is necessary so that possible subsequent flood flows may be similarly detained in the reservoir and their discharge regulated. It is apparent that flood control reservoir operation is largely incompatible with conservation, which requires detention of the stored flood waters until released upon demand for beneficial use. It is considered probable that under economic pressure attendant with ultimate development in California, flood control operation of reservoirs will give way in some measure to their operation for conservation.

Improvement of stream channels for flood protection may also oppose the interests of water conservation. Under natural conditions flood waters leave the stream channels and spread out over wide areas of adjacent alluvial lands. Depending upon permeability and the degree of saturation of the soils, varying amounts of the flood waters percolate to the underlying ground water basins. This is the principal source of replenishment for most of the economically vital ground water basins of California. Confinement of flood waters to restricted channels materially reduces the opportunity for percolation and ground water replenishment. This adverse effect is even more pronounced when the channels are lined with concrete or other impermeable materials, as they are in many instances in areas of acute ground water overdraft, particularly in southern California. To compensate for this impairment of the natural process, or to increase the natural conservation of flood waters in ground water reservoirs, artificial spreading works have been constructed in a number of places. Flood waters, either uncontrolled or temporarily stored in upstream reservoirs, are diverted and conveyed to the spreading grounds and allowed to percolate as rapidly as possible. Beneficial results from such artificial spreading have been obtained in the Santa Clara Valley and in the South Coastal Area, and it is probable that extensive spreading works will be constructed in the future.

Drainage

Drainage of high water table lands is a serious problem in many agricultural areas of California. Large acreages of developed lands have been lost to agriculture by water-logging, and in some instances by excessive salinity, brought about by over-irrigation and careless storage and conveyance of water. Further large areas of potential agricultural land cannot be utilized because of naturally high water tables. Extensive drainage works have been constructed in most agricultural areas of the State, at both public and private expense, but large areas remain to be reclaimed. Such enterprise is doubly desirable in future efforts of California to meet its water requirements. Consumptive use of water from the high water table lands is a substantial economic loss, while the water salvaged in maintaining lower water tables may ordinarily be put to beneficial consumptive use.

Salt Balance

The use of ground water storage capacity in conserving and regulating both local and imported water supplies, particularly those supplies intended to be used consumptively by irrigated agriculture, requires the consideration of the salt balance involved in the use and re-use of the available supplies.

The problem of salt balance exists in most of the developed ground water basins of California, and must be considered if the basins are to retain their important place in conservation and utilization of water in the State. The solution involves induced drainage of water from the basins in amounts sufficient to maintain satisfactory mineral quality therein. The amount of water so drained away will constitute a future demand on the developed water supply.

Practically all natural waters contain mineral salts of calcium, magnesium, sodium, and potassium in varying amounts, present in the waters in the form of carbonates, sulphates, and chlorides. After application of water on the land, that part which is not consumptively used and which does not drain off on the surface will percolate to the main body of ground water in free ground water basins. As a result of use some salt compounds will be given up in promoting growth or in combining with soil elements. Conversely, percolating water will absorb other salt compounds in passing through the soil between the surface and the water plane. Under natural conditions most ground water basins tend to fill with water and to overflow in the lower portions, thereby flushing out soluble salts contained in water originating on the tributary watershed and overlying lands. When aquifers in the basin are tapped by wells, the pumping draft lowers ground water levels to such an extent that in many cases the natural flushing of the basins ceases. Since the pumped water is largely used on overlying lands, soluble salts accumulate within the basin and tend to degrade the quality of the ground water in storage. If the situation is such that no discharge of water from the area, either surface or subsurface, occurs, in the course of time the concentration of salt compounds in the remaining water will become so great as to inhibit its use as a source of water supply. This is particularly true in the case of irrigation supplies, as crops generally have rather low tolerances for dissolved salts.

In general, a salt balance can be established in a given area by deliberately inducing outflow of water from the area in such amount that the total quantity of mineral salts exported is the same as the quantity imported. Under these conditions the long-time mean quantity of salts is maintained as a constant quantity. The maintenance of such balance, or the removal of a total amount of salt from an area exceeding the salt input to the area (termed "favorable salt balance") does not necessarily imply lack of damage to the lands and crops. When existing ground water in storage is substantially more saline than the waters currently applied on the surface, the total quantity of salt in the effluent water is likely to be greater than that in the influent to the same area, and this condition will continue until all existing saline ground waters have been displaced. It is also important to determine whether a favorable salt balance is being maintained in the root zone of the irrigated crops, as accumulations of salt compounds in that zone will prevent the successful culture of many irrigated crops.

Water Quality

Full development of the waters of California for all beneficial uses will require thorough consideration of problems of water quality.

Three general classes of water quality problems have been found to exist in California:

(a) The use of water to carry away wastes resulting from urban and industrial development.

(b) Impairment of the quality of water as a result of its development and beneficial use, (such as return irrigation water, sea-water intrusion, and damage to quality of ground waters resulting from improperly constructed, defective, and abandoned wells).

(c) Naturally occurring poor quality water.

Regulatory machinery to prevent unreasonable and adverse impairment of the quality of receiving waters to the detriment of the beneficial uses of the waters, from the discharge of sewage or industrial wastes, the first of the foregoing problems, was established in California in 1949. Section 13005 of the Water Code defines "pollution" as

> " . . . an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which does not create an actual hazard to the public health but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational or other beneficial uses."

and "contamination" as

> " . . . an impairment of the quality of the waters of the State by sewage or industrial waste to a degree which creates an actual hazard to the public health through poisoning or through the spread of disease. 'Contamination' shall include any equivalent effect resulting from the disposal of sewage or industrial waste, whether or not waters of the State are affected."

Control of "pollution" is the responsibility of nine regional water pollution control boards. The State Water Pollution Control Board can review the acts of a regional board if it appears that appropriate action has not been taken by the regional board. Each of the regional boards has authority to prescribe requirements as to the nature of any sewage or industrial waste discharge or the conditions to be maintained in the receiving waters. Both the state and regional boards have authority to formulate policy for the control of water pollution.

The power of abatement of contamination is vested in the state and local health officers.

Most of the problems caused by disposal of sewage and industrial wastes that previously existed in California have been corrected by the work of these agencies, and progress is being made on correction of the remainder as well as prevention of damage from new waste discharges.

The Division of Water Resources was given authority in 1950 by Sections 229, 230, and 231 of the Water Code to study all water quality problems in the State, to report on them, and to recommend corrective action to the Legislature and the regional water pollution control boards. Studies have been initiated by the Division of many of the more pressing problems. Those completed to date have been concerned with specific conditions in limited areas. Studies are now in progress on such aspects as water quality objectives necessary for water resource developments of statewide magnitude, salt balance in ground water basins, minimum standards for well construction and abandonment, sea-water intrusion to coastal ground water basins, and effects of irrigation return flows in the lower reaches of streams. Results of these current studies will be taken into account in the development of The California Water Plan.

A discussion of the general aspect of the quality of water problems in California, particularly as it relates to water requirements, is presented in Appendix I, "Water Quality Considerations Affecting Use of the Waters of California."

Costs of Water

As has been stated, the relative costs of water have a considerable influence on the nature and amount of water utilization in the various parts of California, particularly as they affect the types of prevailing irrigated crops and industries, methods of water conservation and use, and efficiencies attained in conservation, distribution, and application of water. In general, the effects are less apparent in connection with urban than with agricultural use of water. However, high municipal water charges tend to prevent the establishment of certain large water-using industries. They may in some cases reduce the per capita use of water, but this effect was not demonstrated in studies of the relationship of water cost to per capita use in connection with metered deliveries, recently conducted in the San Francisco Bay Area. It has been generally observed throughout California, however, that by installing water meters and imposing metered rates the per capita use of water is reduced in amount from that prevalent during prior flat rate service.

Extensive study of the cost of water in California was not made in connection with the current investigation. However, a few examples will serve to indicate the range in unit cost for irrigation and urban supplies in various parts of the State. In the Turlock Irrigation District in the San Joaquin Valley, the assessment for irrigation water now averages about $1.25 per acre per year, and entitles the farmer to a maximum of four acre-feet of water per acre. This extremely low charge is made possible by efficient district management and by subsidy through income from sale of hydroelectric power produced by the district. In contrast, the average annual assessment in one irrigation district in southern California is about $24 per acre per year. To this is added water charges that result in a total annual cost of water of from about $60 to $70 per acre, depending upon the amount of pumping required to reach the land to be served. On the average, the cost to the farmer of pumping irrigation water from wells in California is of the order of about four to six cents per acre-foot per foot of lift. In the Central Valley Area the cost to a typical irrigator pumping 1,000 gallons per minute from a depth of 80 feet is approximately $3.50 per acre-foot. This includes costs of power, operation and maintenance, and capital investment.

The cost of urban water in California shows similar variation. In many municipalities of the Sacramento Valley water is plentiful and low flat rate charges prevail. In the City of Sacramento flat rates average about $1.50 per month for single-family residences, and wholesale rates are correspondingly low. Rates for single-family domestic metered service by major utilities in the San Francisco Bay Area vary from about 30 to 40 cents per 1,000 gallons. For an average consumer these rates result in monthly charges of from about $3.00 to $4.00. Average wholesale rates in the Bay Area for industries and other large water users vary from about 25 to 30 cents per 1,000 gallons. In the Los Angeles Metropolitan Area single-family residential rates average from about 20 to 40 cents per 1,000 gallons. Inasmuch as the per capita water use is slightly greater in Los Angeles than in San Francisco, the average domestic consumer's monthly bill varies from about $3.00 to $5.00. Wholesale water rates in the Los Angeles area vary from about 12 to 30 cents per 1,000 gallons.

It is believed that the cost of water will not be a limiting factor in ultimate development of the water resources of California. Today, as in the past, expensive urban water supply works, resulting in relatively high charges to consumers, are readily financed to meet existing shortages or anticipated future water needs. It is indicated that urban communities will always be able and willing to pay the cost of water to meet their municipal needs. Furthermore, it is considered probable that under pressure of future demands for agricultural produce the water necessary for a greatly expanded irrigation development will be provided, at whatever cost may be required. For these reasons, in current studies in preparation of The California Water Plan, the indicated present cost of water and present financial feasibility are not necessarily being taken as determining factors in selection of project features. Many works financially infeasible today will undoubtedly be financed and constructed in the future. In the current studies, however, full consideration is being given to indicated relative costs of possible alternative project features, with choice being given to those demonstrating the least cost.

CHAPTER II

METHODS AND PROCEDURES

The complexity and magnitude of the task of assembling and interpreting basic data presented in this bulletin, and of forecasting growth of California and her water requirements, justify some explanation of the methods and procedures involved. In general, the process included: (1) the collection of survey data and information from all available sources, (2) the conduct of supplemental surveys as required, (3) compilation of the data and information in presentable form, (4) interpretation and projection of the data and information, and (5) reference of the results to the best available authorities for review based on their experience and judgment. The methods and procedures employed are described in this chapter, and in order to avoid repetition are only referred to in ensuing chapters when significant departures from the general practice were involved.

DEFINITIONS

The following definitions of certain terms and concepts, as used in this bulletin, are presented to facilitate understanding of the ensuing subject matter.

Annual—This refers to the 12-month period from January 1st of a given year through December 31st of the same year, sometimes termed the "calendar year."

Seasonal—This refers to any 12-month period other than the calendar year.

Precipitation Season—The 12-month period from July 1st of a given year through June 30th of the following year.

Runoff Season—The 12-month period from October 1st of a given year through September 30th of the following year.

Average Monthly Temperature—The monthly average of daily averages of maximum and minimum temperatures.

Mean Period—A period chosen to represent conditions of water supply and climate over a long series of years. For purposes of the current investigation the mean precipitation period embraces the 50 seasons from 1897-98 through 1946-47, and the mean runoff period the 53 seasons from 1894-95 through 1946-47.

Mean—This is used in reference to arithmetical averages relating to mean periods.

Average—This is used in reference to arithmetical averages relating to periods other than mean periods.

Present—This is used generally in reference to land use and water supply conditions prevailing during the period from 1945-46 through 1952-53.

Ultimate—This is used in reference to conditions after an unspecified but long period of years in the future when land use and water supply development will be at a maximum and essentially stabilized.

Water Utilization—This term is used in a broad sense to include all employments of water by nature or man, whether consumptive or nonconsumptive, as well as irrecoverable losses of water incidental to such employment, and is synonymous with the term "water use."

Factors of Water Demand—Those factors pertaining to rates, times, and places of delivery of water, quality of water, losses of water, etc., imposed by the control, development, and use of the water for beneficial purposes.

Water Requirement—The water needed to provide for all beneficial uses and for all irrecoverable losses incidental to such uses.

Present Supplemental Water Requirement—The additional water needed to provide for all present beneficial consumptive uses of water and for irrecoverable losses incidental to such use over and above the safe yield of the present water supply development.

Probable Ultimate Supplemental Water Requirement—The difference between the present and probable ultimate water requirement, added to the present supplemental water requirement if such exists, or minus the ultimate developed water supplies of the Friant-Kern, Madera, and Contra Costa Canals in the areas where they apply.

Consumptive Use of Water—This refers to water consumed by vegetative growth in transpiration and building plant tissue, and to water evaporated from adjacent soil, from water surface, and from foliage. It also refers to water similarly consumed and evaporated by urban and nonvegetative types of land use.

Applied Water—The water delivered to a farmer's headgate in the case of irrigation use, or to an individual's meter in the case of urban use, or its equivalent. It does not include direct precipitation.

Effective Precipitation—That portion of the direct precipitation which is consumptively used and which does not contribute to stream flow or percolate to the ground water.

Irrigation Efficiency—The ratio of consumptive use of applied irrigation water to the total amount of water applied, expressed as a percentage.

Irrigation Water Service Area Efficiency—The ratio of consumptive use of applied irrigation water in a given service area to the gross amount of water delivered to the area, expressed as a percentage.

Natural Flow—The flow of a stream as it would be if unaltered by upstream diversion, storage, import, export, or change in upstream consumptive use caused by development.

Impaired Flow—The actual flow of a stream with any given stage of upstream development.

Aquifer—A geologic formation or structure sufficiently permeable to yield water to wells or springs.

Free Ground Water—A body of ground water not immediately overlain by impervious materials, and moving under control of the water table slope.

Confined Ground Water—A body of ground water immediately overlain by material sufficiently impervious to sever free hydraulic connection with overlying water, and moving under pressure caused by the difference in head between the intake or forebay area and the discharge area of the confined water body.

Safe Surface Water Yield—The maximum dependable rate at which surface water would be available throughout a chosen critically deficient water supply period, with a given stage of surface water supply development.

Safe Ground Water Yield—The maximum rate of net extraction of water from a ground water basin which, if continued over an indefinitely long period of years, would result in the maintenance of certain desirable fixed conditions. Commonly, safe ground water yield is determined by one or more of the following criteria:

1. Mean seasonal extraction of water from the ground water basin does not exceed mean seasonal replenishment to the basin.
2. Water levels are not so lowered as to cause harmful impairment of the quality of the ground water by intrusion of other water of undesirable quality, or by accumulation and concentration of degradants or pollutants.
3. Water levels are not so lowered as to imperil the economy of ground water users by excessive costs of pumping from the ground water basin, or by exclusion of users from a supply therefrom.

Ground Water Overdraft—The rate of net extraction of water from a ground water basin in excess of safe ground water yield.

Quality of Water—Those characteristics of water affecting its suitability for beneficial uses.

Pollution—Impairment of the quality of water by sewage or industrial waste to a degree which does not create a hazard to public health, but which adversely and unreasonably affects such water for beneficial uses.

Contamination—Impairment of the quality of water by sewage or industrial waste to a degree which creates a hazard to public health through poisoning or spread of disease.

Degradation—Impairment in the quality of water due to causes other than disposal of sewage and industrial wastes.

GEOGRAPHICAL SUBDIVISION OF CALIFORNIA

For purposes of this bulletin the State was divided into seven major hydrographic areas, coinciding with those utilized in Bulletin No. 1, "Water Resources of California," and these major areas were further subdivided into "hydrographic units." The portion of California included within each hydrographic area and the numbers and names by which they are designated are:

1. North Coastal Area. Lower Klamath Lake and Lost River Basins, and all basins draining into the Pacific Ocean from the California-Oregon state line southerly to the northern boundary of Lagunitas Creek Basin in Marin County.

2. San Francisco Bay Area. All basins draining into San Francisco, San Pablo, and Suisun Bays, and into Sacramento River downstream from Collinsville; Winter and Browns Islands in Contra Costa County; basins west of the eastern boundary of Kirker Creek Basin in Contra Costa County; and basins directly tributary to the Pacific Ocean from the northern boundary of Lagunitas Creek Basin to the southern boundary of Pescadero Creek Basin, in San Mateo and Santa Cruz Counties.

3. Central Coastal Area. All basins draining into the Pacific Ocean from the southern boundary of Pescadero Creek Basin in Santa Cruz County, to the southeastern boundary of Rincon Creek Basin in the western part of Ventura County.

4. South Coastal Area. All basins draining into the Pacific Ocean from the southeastern boundary of Rincon Creek Basin to the California-Mexico boundary.

5. Central Valley Area. All basins draining into the Sacramento and San Joaquin Rivers above the eastern boundary of the San Francisco Bay Area near Collinsville, including Goose Lake Basin in Modoc County.

6. Lahontan Area. All basins east of the Santa Ana and Los Angeles River Basins and all basins east of the Central Valley Area, between the California-Oregon boundary and the southern boundary of basins draining into Antelope Valley and Mojave River, and into Dry Lake Basin near the Calfornia-Nevada line north of Ivanpah.

7. Colorado Desert Area. All basins east of the South Coastal Area that drain into the Colorado River within California; also Salton Sea Basin and local sinks between the southern boundary of the Lahontan Area and the California-Mexico boundary.

The hydrographic units, into which the major hydrographic areas were subdivided, were established for purposes of required hydrologic study. Descriptions of the units are contained in Appendix C. The hydrographic unit boundaries were determined from consideration of water supply and related water service. Boundaries were established in the Central Valley Area so that a major stream basin includes two units, one an upstream mountainous or predominantly water-source unit, and the other a downstream valley floor or predominantly water-using unit. Boundaries of hydrographic units in the North Coastal, Central Coastal, South Coastal, Lahontan, and Colorado Desert Areas encompass entire stream basins in most cases. The San Francisco Bay Area, because of its highly developed urban nature, was divided into units designed to facilitate study of established water service areas, as were the metropolitan areas in and around Los Angeles and San Diego in the South Coastal Area.

Locations of the major hydrographic areas and of the hydrographic units, together with their numerical designations, are shown on Plate 8, "Major Hydrographic Areas and Hydrographic Units."

CLASSIFICATION OF WATER SERVICE AREAS

The lands of California were segregated into three broad areal classifications according to the nature of their present or expected future water service for the purpose of determining consumptive water requirements, as follows:

(1) Irrigable lands—lands presently irrigated, as well as those additional lands which are suitable for irrigation under conditions of probable ultimate development. The lands so classified were further segregated on the basis of types of principal crops.

(2) Urban and suburban areas—lands which are presently, or will probably ultimately be devoted to urban and suburban use. In the San Francisco Bay Area and in most of the South Coastal Area, these lands were further classified on the basis of principal types of urban land use, such as residential, commercial, industrial, etc.

(3) Other water service areas—the remaining area of the State, other than the irrigation and urban and suburban water service areas, which contains lands either now or in the future requiring water service, but which cannot be placed in either of the foregoing classifications. Under present conditions, this area receives water service for limited specialized purposes such as recreational development, isolated industrial plants, military establishments, evaporation from valley floor reservoirs in the Central Valley Area, wild fowl ponds, etc., and the actual aggregate water service area is relatively insignificant. For this reason, these remaining lands were not segregated comprehensively as regards types of present land use, and are hereinafter referred to as "unclassified areas." It was assumed that under conditions of probable ultimate development, in addition to allowances for expansion of irrigation and urban and suburban water service areas, all of the remaining lands of the State will require water service. This large area will be generally subject to only sparse development even under such conditions of ultimate development, and is hereinafter referred to as "other water service areas."

Irrigation is presently by far the most important consumptive employment of water in California, in terms of quantity of water requirement, and will probably maintain this position under conditions of ultimate development. From a quantitative standpoint, the next most important consumptive water requirement is for urban and suburban developments. Other consumptive water requirements, considered quantitatively, are minor in amount. On the basis of the relative importance of the irrigation water requirement, particularly as it pertains to planning for water resource development, it follows that the greatest emphasis in studies for this bulletin was placed on the determination of present and probable ultimate irrigation water service areas. Urban and suburban water requirements for present and probable ultimate urban and suburban water service areas were studied in considerable detail, although not to the same degree of intensity as the irrigation requirements. Urban and suburban use of water in the case of the three cited major metropolitan areas will be paramount in the future, and therefore urban and suburban water service areas included therein were given detailed treatment and emphasis. In accordance with its relatively minor consumptive water requirement, the third general classification, "other water service areas," was given relatively less detailed study and consideration.

MAPS

A series of maps is included with this bulletin depicting present and probable ultimate water service areas throughout California. This series is designated as Plate 9, and is entitled "Classification of Lands for Water Service From The California Water Plan." Shown in distinctive colors are the present irrigation water service areas, urban and suburban water service areas, and additional lands considered to be future irrigation or urban and suburban water service areas. "Other water service areas" under ultimate conditions of development comprise the remainder of the State. Present military areas, as well as tidal and submerged lands subject to possible future reclamation in the San Francisco Bay Area, are shown by distinctive conventions. The series of maps also shows the location of principal physical and cultural features, place names, and latest available topography. The individual map sheets, 26 in number, each cover one degree of latitude and varying degrees of longitude, and are drawn to a scale of 1 to 500,000. The maps were adapted from a base map published by the United States Geological Survey in 1952 and show only those water service areas of one square mile or greater in area. In addition, there is an index sheet which identifies by number the various portions of the State covered by the individual map sheets. On Plate 1, "Water Service Areas for The California Water Plan," the present irrigation and urban and suburban water service areas and the additional lands suitable for future irrigation and urban and suburban development, shown on the foregoing series, are generalized for the purpose of presenting a composite of present and probable ultimate water service areas for the State as a whole.

Greater detail than was possible with the foregoing map series was desirable for presently highly developed lands around San Francisco Bay and in and around Los Angeles and San Diego. Two supplemental series of maps cover these metropolitan areas at a scale of 1 to 125,000, and show the present residential, commercial, industrial, and irrigated agricultural lands in distinctive colors. Lands with certain specialized uses, such as salt ponds, which depart materially in water requirement from that of other industrial lands, are shown by special conventions. The San Francisco Bay Area is covered by a series of 11 map sheets and an index sheet, designated Plate 10, and entitled "Present Land Use in San Francisco Bay Area." Coverage of the Los Angeles and San Diego Metropolitan Areas consists of a series of nine and two map sheets, respectively. One index sheet serves for both of these latter metropolitan areas, and the series is designated Plate 11, and entitled "Present Land Use in Los Angeles and San Diego Metropolitan Areas." Recent United States Geological Survey quadrangles served as the base for preparation of these map series.

In addition to the foregoing general map coverage, several specialized maps are included to illustrate the subject matter of this bulletin. Plate 3 shows the irrigation and water storage districts in the State. These agencies supply the majority of the irrigation water requirements of the State. Plate 4 depicts the known ground water basins of California, as well as those additional areas of valley fill that may or may not comprise ground water basins at the present time or in the future. Plate 5 shows the present hydroelectric power development in the State, including power plants, principal transmission lines, and reservoirs used principally for hydroelectric power production. Plate 6 shows the timber-producing lands of the State and the general location of auriferous gravel deposits. Plate 7 shows the recreational areas including national parks, monuments, and forests, and state beaches and parks. Plate 8 shows the boundaries of the seven major hydrographic areas of California, and of the hydrographic units into which the areas were divided for purposes of hydrologic analysis. Plate 12 shows the principal public and private agencies and water supply works serving the San Francisco Bay Area at the present time, while Plate 13 depicts similar information for the Los Angeles and San Diego Metropolitan Areas.

GENERAL DESCRIPTION OF METHOD OF DETERMINING WATER REQUIREMENTS

The basic method used in estimating water requirements was, first, to determine the areas of various types of water service according to the classifications previously described, based generally on survey data, and, second, to derive appropriate unit values of consumptive water use for each particular class and type of land use, based largely on available experimental and investigational data. Unit values of consumptive use of water were subsequently applied to the established water service areas to estimate the total consumptive use. The water service area efficiency was then applied to the consumptive use figure to determine the total water requirement, generally measured in terms of consumptive use of applied water plus all unavoidable losses.

With respect to water requirements for "other water service areas," there were variations from the foregoing procedure in that derivation of some of the water requirements was made on a per capita or unit of production basis rather than on an areal basis.

The supplemental water requirements under conditions of probable ultimate development generally were evaluated as the difference between present and ultimate water requirements, plus any existing present supplemental water requirement. Where a present deficiency in available water supply exists, the safe yield of the present water supply development was determined from available data and compared with the present water requirement, the difference being the present supplemental water requirement.

Data secured from field surveys and from office analysis of pertinent estimates for ultimate development are presented in tables pertaining to each hydrographic area. The tabular data were generally rounded to three significant figures, with the totals rounded as necessary to accord with the same standard.

SURVEYS OF PRESENT WATER SERVICE AREAS

Data as to the nature, location, and areal extent of lands in California to which water other than precipitation is presently applied were obtained, insofar as they were available, from federal, state, and local agencies. These data generally were based on results of field surveys, segregated in accordance with various classes and types of land use, and are regularly determined by many water service agencies as a part of their operational procedures. The Bureau of Reclamation of the United States Department of the Interior, in planning for and operating the Central Valley Project, has made land use surveys of much of the irrigated area on the floor of the Central Valley. The Division of Water Resources, in connection with recent and current water resources investigations, has surveyed water-using lands in many areas of the State. Additional field surveys to supplement the available land use information were conducted in order to obtain complete coverage of water service areas in California. Because of the relatively great importance of the metropolitan areas in and around San Francisco Bay, Los Angeles, and San Diego, special detailed land use surveys were conducted in these areas.

Surveys of present water service areas conducted during the investigation were accomplished generally by field inspection, using aerial photographs or suitable maps to delineate boundaries of the various classifications. Areas so delineated were then measured, and the data compiled in combination with that from other sources. Combined data were then tabulated as desired for presentation in this bulletin.

Within the scope of the present investigation, it was impracticable to survey during any single season all areas receiving water service in California. Tabulations of present water service areas included herein represent a composite of survey data covering the period from 1946 through 1953, which is the period referred to in this bulletin in discussing present conditions of development in California. The pictorial presentation of present water service areas shown on the individual sheets of Plate 9 depicts all lands that received water service during one or more years of this designated present period.

Irrigated Lands

Data from surveys of irrigated lands in California were tabulated in such form as to permit grouping of crops having similar water-using characteristics, and which were raised under similar agricultural practices. The crop groups varied throughout the State, dependent upon the nature of the survey data and the distribution of crops. Indicative of the nature of the irrigated crop groupings is the following for the Central Coastal Area:

Alfalfa	Hay, seed, and pasture
Pasture	Grasses and legumes, other than alfalfa, used for livestock forage
Orchard	Deciduous fruit, nuts, and olives
Citrus	Oranges, lemons, grapefruit, and avocados
Vineyard	All varieties of grapes
Truck crops	Intensively cultivated fresh vegetables, including tomatoes, lettuce, artichokes, brussels sprouts, cabbages, carrots, peppers, broccoli, flower seed, and nursery crops
Sugar beets	
Miscellaneous field crops	Dry beans, milo, corn, hops, hay, grain, etc., and unsegregated sugar beets in Santa Barbara County

The coverage of the land use surveys in most parts of the State was limited to areas of irrigated crops. However, on the valley floor of the Central Valley Area, in the three major metropolitan areas, and in several localities where special water resource investigations had been conducted, the data obtained were complete on an areal basis, embracing all types of land use, both natural and man-made, within the survey boundaries.

Delineation of irrigated lands was largely accomplished on the basis of their gross area. That is, in general, the included areas of roads, railroads, rights of way, farm lots, and other nonagricultural parcels within the irrigated lands were not segregated at the time of the survey. These items were later evaluated by application to the gross surveyed areas of appropriate percentage factors, determined from detailed surveys of representative sample plots. In the case of most mountain and foothill areas and certain other relatively sparsely developed agricultural areas, irrigated lands as originally plotted on aerial photographs in the field were assumed to represent net areas. This was permissible because the included rights of way and nonagricultural lands were very minor in extent.

At the request of the Division of Water Resources, irrigated lands within the boundaries of national forests and national parks and monuments were surveyed by the federal agencies having administrative jurisdiction of these lands. Each such agency reported the irrigated acreage by types of crop, location, and quantity of water pumped or diverted for the purpose of irrigation.

Information as to the sources of data regarding areas of irrigated lands and approximate dates of the surveys is presented in Appendix D.

Urban and Suburban Areas

In most of the State the areas classified in this bulletin as urban and suburban consist of those lands in and adjacent to towns and cities that are characterized by commercial, industrial, residential, and related community types of development. Such a typical urban and suburban area might be composed of a central business and commercial district, one or more adjacent industrial districts, and surrounding residential and suburban districts, together with included parks, schools, streets, airfields, vacant lands, etc.

Lands devoted to urban and suburban development in the Central Valley Area and in most of the South Coastal Area, and in several other localities where special water resources investigations have been conducted, were determined in varying detail from field survey data. In order to make this determination, it was usually the procedure to assume an arbitrary criterion for delineating the boundary between such urban and suburban lands and surrounding lands. Generally, the boundary was established to include all lands in the urban and suburban classification where at least 10 per cent of the gross area was occupied by designated urban and suburban types of land use. In the South Coastal Area, however, no lines were drawn delimiting the gross urban and suburban areas, and all lands devoted to these types of use were included in the totals even when isolated from urban centers. In the Klamath River drainage basin estimates were made of all the urban and suburban areas by converting population to acres by the application of a density factor.

The areal extent of urban and suburban lands throughout the remainder of California was determined by measurements made on the latest and most accurate available maps or photographs. In the case of a few small communities where no other appropriate information was available, the urban and suburban areas were computed by dividing 1950 census population figures by the average population density of similar towns in the vicinity.

Metropolitan Areas

As in the case of irrigated lands in the agricultural portions of the State, detailed surveys of land use in the three large metropolitan areas, in and around San Francisco, Los Angeles, and San Diego, were made for the purpose of grouping development types having similar characteristics as regards water use. Recent zoning maps of the areas being surveyed were obtained from the planning agency of the responsible local political subdivision, for use in determining the various prevailing types of urban land use, as well as their general locations within the area. The principal types of land use considered were residential, commercial, and industrial. In those cases where the indicated unit values of water use departed materially from the average for these principal types, further subdivisions were made. Thus, multiresidential areas were segregated from residential, and tank farms, airports, and other low water-using industries were segregated in the industrial areas.

Available recent maps or aerial photographs were then obtained and provisional determination of the various land use types was accomplished in the office by inspection of the maps and aerial photographs in conjunction with the zoning map. Blocks of the area were identified as to their prevailing urban land use type and then field-inspected, resulting in verifying or changing the office determinations as required. Following this gross classification of the blocks, the net area actually devoted to the indicated prevailing urban type of use was determined by eliminating the areas of streets, highways, and vacant lots, which were estimated as percentages of the total, and by similarly estimating the percentages of the total area represented by land use types differing from the dominant type in the block. Where agricultural and urban uses of land were interspersed, either a crop classification was estimated for the irrigated agricultural portion and expressed in terms of percentage of the whole area, or the irrigated lands were classified as to crop type during the survey.

Unclassified Areas

Certain present water-using lands in California, not falling into the foregoing major classifications, were difficult to delineate, while in the case of others the areal extent bore little relationship to the amount of the water requirement. Such present areas, therefore, were not surveyed and delineated in detail, but the water requirements were generally determined on a per capita or unit of production basis, rather than on an areal basis. For purposes of this bulletin, this category of present water service area is referred to as "unclassified."

In general, the unclassified area receiving water service includes scattered developed portions of national forests, parks and monuments, public beaches and parks, private recreational areas, military reservations, wild fowl refuges, and artificial water surfaces on the valley floor of the Central Valley Area that consume water by evaporation. Military reservations in the South Coastal Area, however, were not segregated as a separate land use type, the included water service areas being assigned to the appropriate irrigated agricultural or urban and suburban classification. The extent of unclassified lands receiving water service was estimated on the basis of information from agencies having jurisdiction and from any other available competent sources. The determination of artificial water surface areas was largely based on data compiled in a publication of the State Division of Water Resources, entitled "Dams Within Jurisdiction of the State of California," February 1, 1950.

METHOD OF FORECASTING ULTIMATE WATER SERVICE AREAS

In forecasting the probable ultimate water service areas of California, the anticipated extent of future urban and suburban types of development was first determined. Existing urban centers and surrounding suburban devlopments were assumed to generally constitute the nuclei for ultimate urban and suburban water service areas, and it is believed that future growth of this type will be largely in and around such present centers. The remaining lands of the State were surveyed to determine the areas suitable for irrigated agricultural development. It was assumed that all such suitable lands will ultimately be developed and served with water for irrigation. The lands not assigned to either of the foregoing major classifications were not segregated in detail with regard to their expected ultimate type of land use. It was assumed, however, that ultimately all of these remaining lands will contain at least sparse development requiring water service, and, as previously stated, they are herein designated "other water service areas."

The use of water for irrigation creates the major water requirement in California, a condition that is anticipated to continue even under probable ultimate conditions of development. Consequently, the forecast of the ultimate irrigated area of the State was of primary importance in estimating the ultimate water requirement. The methods used in the determination of irrigable areas and irrigated lands under probable ultimate conditions are outlined in considerable detail in the ensuing section.

Irrigable and Irrigated Lands

The extent and location of the irrigable lands of California were determined by collecting, reviewing, and compiling appropriate land classification survey data available from other agencies, supplemented by data obtained from field surveys conducted as required by the Division of Water Resources during the investigation. Agencies whose land classification survey data were so used include the Bureau of Reclamation of the United States Department of the Interior, the Bureau of Agricultural Economics of the United States Department of Agriculture, and the Agricultural Experiment Station of the University of California. Appendix E presents a tabulation of the areas classified by the aforementioned agencies.

New developments in irrigation practice in recent years and new irrigated crops have modified former concepts of the types of land suitable for irrigated agriculture. Lands formerly considered nonirrigable because of excessive slope or roughness of topography are now being irrigated satisfactorily by sprinklers, which make feasible the irrigation of nearly all land otherwise suitable and capable of holding the soil against erosion. The successful irrigation of ladino clover and certain other irrigated forage crops has resulted in a rapid expansion of the acreage devoted to irrigated pasture, and has justified the development of lands with shallow soils formerly considered nonirrigable. These recent technological developments made it necessary to review and revise some of the land classification data supplied by other agencies which had been based on past standards, and to correlate earlier standards with those established by the Division of Water Resources for the present investigation.

Standards for Determination of Irrigability of Lands. The suitability of land for irrigation development is influenced by many factors. Those factors relating to the production and marketing of climatically adapted crops have marked influence upon the successful development of certain types of land for irrigation. The cost of water and the size, shape, and location of the parcels of land with respect to the water supply are also significant factors. Furthermore, climatic conditions influence crop adaptability and thus indirectly affect the irrigability of the lands. Contrasting with these more or less indirect factors of irrigability are the physical characteristics of the land and the inherent conditions of the soil itself which directly affect the adaptability of the land for irrigation development, and which are generally subject to relatively little change with variation in local or general economic conditions.

Studies for this bulletin resulted in the determination that the most permanent and significant classification of the lands, as regards their suitability for irrigation development, would be obtained if the standards were based upon the more stable physical characteristics of the land and inherent conditions of the soil. These standards kept the cited economic factors as separate variables, making it possible to reappraise the present land classification at any future date in view of economic conditions existing at that time. The land classification standards used in studies for this bulletin, therefore, were based upon physical factors and inherent conditions of (1) soils, (2) topography, and (3) drainage.

(1) Soils. The characteristics of soils that principally establish their suitability for irrigation are depth, texture, and structure. These physical factors to a large extent determine the moisture-holding capacity, the root zone area, the ease of cultivation and irrigation, and the available nutrient capacity of the soils.

(2) Topography. Topographic conditions considered in the land classification included the degree of slope, the undulation of the land, and the amount of cover as represented by loose rock and rock outcroppings. These factors directly affect the ease of irrigation and determine the type of irrigation practice best suited to provide the land with water in sufficient quantity to meet crop needs, without soil erosion or excessive losses of water through surface runoff.

(3) Drainage. Drainage is highly important in determining the irrigability of land, as the problems of salinity and alkalinity are closely associated with it. For purposes of the present studies it was assumed that under conditions of ultimate development most lands physically capable of drainage reclamation will be reclaimed. Thus, in the land classification relatively little land was determined to be nonirrigable because of its present condition as regards drainage, if it appeared that drainage and reclamation would be practical in the future.

Results of the land classification surveys presented herein are not segregated into several classes as regards their adaptability to irrigation, although much of the data was field mapped and compiled in that manner. Maps and tabulations of such data obtained from other agencies involved somewhat different systems of classification, and in many cases could not readily be correlated directly with the land classes established for use by the Division of Water Resources. Furthermore, in many parts of the State the scale and detail of available base maps would not allow delineation of several irrigable land classes. In these cases, necessity limited the classification to a basic determination of whether or not the land was predominantly irrigable. It is probable that acreage determinations in future studies of irrigable lands in many areas of California will deviate from acreages as shown herein. The planning for definite future projects in those areas requires that stricter standards as to irrigability will be applied due to economic factors concerned with the feasibility of developing water supplies. In general, the lands of California classified as irrigable in this bulletin meet the minimum requirements set forth in Table 1.

TABLE 1
STANDARDS FOR CLASSIFICATION OF LANDS AS IRRIGABLE

Land characteristics	Minimum requirements
Soils	
Texture	Loamy sand to permeable clay.
Depth	
To sand, gravel, or cobble	18 inches of good free-working soil of fine sandy loam or heavier, or from 24 to 30 inches of lighter textured soil.
To bedrock	At least 18 inches over shattered bedrock or tilted shale bedrock; or 24 inches over massive bedrock or hardpan.
Topography	
Slopes	Smooth slopes up to no more than 30 percent in general gradient in reasonably large-sized bodies sloping in the same plane; or undulating slopes which are less than 20 percent in general gradient.
Rock cover	No more than enough loose rock and rock outcroppings to moderately reduce productivity and interfere with cultural practices. Varies with soil depth and topographic conditions.
Erosion	No more than moderate erosion, with very few gullies which are not crossable by tillage implements.
Drainage	
Soil and topography	Such that moderate farm drainage may be required, but without excessive cost.
Salinity	Total salts in the soil solution do not exceed 0.5 percent, except in readily drained soils where reclamation appears feasible.
Alkalinity	The pH value is 9.0 or less, unless the soil is calcareous in which case higher values may be allowed. If there is evidence of black alkali a lower pH value may be limiting.

Land Classification Survey Procedure. The field mapping procedures utilized during the investigation for the delineation of irrigable lands were basically the same throughout the State. The character of the soils was established by examination of materials from test holes, road cuts, and ditch banks, together with observation of the type and quality of natural vegetation or crops. In classifying lands of the Mojave and Colorado Deserts, but excluding those areas having rights in and to the waters of the Colorado River, this procedure was supplemented with laboratory determinations of moisture-holding capacities of soil samples taken from representative lands. The Soil Conservation Service of the United States Department of Agriculture cooperated in this activity by making available laboratory facilities and professional assistance. In general, topographic and drainage conditions were estimated from examination of topographic maps, supplemented and checked by observations in the field. Characteristics of the soils and topographic and drainage conditions were delineated and recorded on the most suitable maps or aerial photographs available. The areas in the Colorado Desert Area having rights in and to the waters of the Colorado River are not classified in this bulletin.

Some variations in the degree of mapping detail were necessary as a result of differences in scales of available base maps. In this connection, the quality and scale of the available topographic maps materially affected the accuracy of determination of topographic and drainage factors. The base maps utilized for a large part of the State were either Geological Survey or Forest Service topographic maps at scales of 1 to 62,500 or 1 to 125,000. Topographic maps were not available in a few areas, and county or State Division of Forestry maps were utilized. In other areas, covered by recent special water resources investigations, the irrigable areas were delineated on aerial photographs and topographic maps at a scale of approximately 1 to 20,000.

Determination of Irrigable Lands That Will Ultimately Be Irrigated. The amount of the land classified as irrigable that will be actually irrigated in any one year under conditions of ultimate development probably will depend on one or more of the following factors:

(1) Quality of the Land. It is anticipated that in the future the higher quality irrigable lands will be intensively developed for irrigation and will remain in relatively continuous operation, whereas lands of poorer quality and of limited crop adaptability will be in production only as favorable economic conditions permit.

(2) Irrigable Areas Utilized for Purposes Other Than Agriculture. It is anticipated that there will always be a portion of the irrigable lands that will be occupied by urban types of development, farm lots, highways, railroads, canals, industrial establishments, etc. The nature of the agricultural development will to some extent determine the amount of certain of these nonagricultural land uses. For example, orchard and truck farming areas ordinarily include more land used for roads and farmsteads than areas where field crops are dominant.

(3) Nonirrigable Lands. The areas of small plots of nonirrigable land included within the areas classed generally as irrigable varied with the detail of the survey and classes of land being surveyed. Analysis of typical areas throughout the State developed factors which were applied to topographically similar areas in order to estimate the magnitude of nonirrigable land included in the general boundaries delineating the area of irrigable lands. The nonirrigable areas and the irrigable areas utilized for purposes other than agriculture were subtracted from the gross irrigable area to determine the net irrigated area under estimated ultimate conditions.

(4) Size, Shape, and Location of the Irrigable Land. It is apparent that small, irregularly shaped plots of land, particularly those isolated from other irrigable lands, cannot be irrigated readily or as completely as large, regular, compact units.

(5) Climatic Influences. Considering lands of equal inherent agricultural quality, it is improbable that as intensive irrigation practices will develop in localities where rainfall is sufficient to support some dry farming, as in areas with a more arid climate where irrigation is an absolute necessity for crop production. The length of the growing season and the danger of unseasonable frosts are other factors that affect adaptability and production of crops, thus indirectly affecting the cultural practices and the intensity of irrigation.

(6) Economic Conditions. The economic effects of crop production costs and net returns are recognized as the most influential factors in limiting the annual irrigated acreage. It is probable that there will always be a tendency to withdraw land from production in years of economic adversity. Inasmuch as the concept of ultimate development adopted for purposes of the present studies presupposes maximum land use within physical limitations, economic factors were not given consideration in determining the probable ultimate irrigated area. This assumption is conservative in relation to water requirements, in that the estimated requirements have thus been maximized in this stage of planning for future water resources development.

The area that will actually be irrigated in California in any one year under probable conditions of ultimate development was estimated by the application of two percentage factors. One factor reflects an estimate of the included land ultimately to be devoted to farm lots, highways, railroads, canals, etc., and varied from 93 to 96 per cent, based on results of analysis of representative irrigation developments. The second factor reflects those items of land quality, inclusion of nonirrigable land, and size, shape, and location of the irrigable land, and varied from 69 to 97 per cent, based on results of analysis of representative irrigation development, as well as experience and judgment. Where the irrigable land was subdivided into classes as to suitability for irrigation, the factors varied with the class. In the case of irrigable lands not so classified, an approximation of the areas of the several classes was estimated in order to provide a basis for using the factors.

Probable Ultimate Crop Pattern. The kinds and amounts of crops that eventually will be grown on lands to be irrigated in California will affect the amount of the ultimate water requirement. Determination of the ultimate crop pattern, therefore, was important in evaluating that requirement.

Methods used in deriving a crop pattern for the State as a whole under conditions of ultimate development are discussed in some detail in Appendix A by Doctor David Weeks, Professor of Agricultural Economics of the University of California. State-wide acreages of the various crops, as derived by Doctor Weeks, were allocated to the seven major hydrographic areas of the State, and, in turn, to hydrographic units within the major areas. The assignment of crop areas was based, in general, on known crop adaptability of the soils and on climatic conditions within the various hydrographic areas and units.

Urban and Suburban Areas

Generally throughout the State, except in the San Francisco Bay Area and most of the South Coastal Area, the lands to be ultimately devoted to urban and suburban types of development were determined from expected ultimate areal population densities and from forecasts of ultimate urban populations. For this large portion of the State, it was assumed that ultimate urban development will occupy the same general localities as at present, but that present land vacancies will be filled and population densities will be increased. It was considered probable that some urban encroachment will occur on presently irrigated or irrigable lands, as well as on nonirrigable lands. The locations of such future encroachment, however, were not specifically predicted nor was the irrigable area reduced to allow for such encroachment.

Detailed studies of land use, available undeveloped land, and present and anticipated densities in the metropolitan centers in and around San Francisco, Los Angeles, and San Diego, indicated that the ultimate population will be approximately 300 per cent greater than at present under a saturated condition of development. It was assumed that the same ratio of population growth under ultimate conditions was generally applicable to urban areas throughout California. Following this assumption, the 1950 populations of present urban centers, as determined by the federal census, were increased by 300 per cent in order to estimate probable ultimate populations.

Present areal population densities were computed from available data, and urban densities were increased to 10 persons per acre under ultimate conditions of development, except for cities in the Central Valley Area where it was assumed that population densities will ultimately increase to 15 persons per acre. Water requirements under ultimate conditions of population density were estimated on the basis of land areas and total population residing therein.

In those hydrographic units where irrigable land is relatively undeveloped at present and where urban development is negligible, the ultimate urban land area was estimated to vary in accordance with the ultimate irrigable area. Studies of presently developed irrigated lands and related urban areas indicated that the urban population will approximate one urban resident per nine acres of irrigated land in the tributary area.

Metropolitan Areas

Water requirements for urban areas will, in general, vary with the type of development, that is, residential, commercial, industrial, etc., and consequently more detailed studies were made to project the probable ultimate land use pattern in the San Francisco, Los Angeles, and San Diego Metropolitan Areas, and in most remaining urban areas in the South Coastal Area, than were made in other urban areas of the State. Such emphasis was necessary because of the relative importance of the large metropolitan centers in determination of future water requirements.

Within the defined boundaries of the San Francisco Bay, Los Angeles, and San Diego Metropolitan Areas, it was assumed that under conditions of ultimate development all suitable land will be occupied by a balanced urban economy. The suitability of the land for urban purposes was determined largely from topographic considerations, although climatic factors influenced the determination in a few instances. The proportions of the several broad classes of urban development, including residential, commercial, industrial, parks and institutions, etc., were projected on the basis of present trends within the respective metropolitan areas and from historic experience in older communities in other parts of the country.

In that part of the South Coastal Area outside of the Los Angeles and San Diego Metropolitan Areas, similar methods and criteria were utilized to determine probable ultimate urban and suburban development. It was assumed that future growth of this nature will be generally adjacent to and in extension of presently established urban centers. Coastal areas bordering on the Pacific Ocean were assumed to be generally suitable to recreational development in the future in accordance with the well established present trend.

Other Water Service Areas

The remaining lands of California, not otherwise classified as either irrigable, urban, or metropolitan under ultimate conditions of development, were assumed to be utilized eventually for miscellaneous purposes requiring a limited water service. It is believed that such land use will be generally sparse, scattered, and minor in extent even when the State is fully developed. Types of land use contemplated for other water service areas include residences, both seasonal and permanent, recreational developments, industrial plants in isolated locations, etc.

Other water service areas comprise groupings established with reference to elevation and existing major jurisdiction and are, respectively, the lands above an elevation of 3,000 feet, lands below that elevation, lands within national forests, parks, and monuments, and those outside the boundaries of such establishments. It was assumed that lands included within other water service areas above the 3,000-foot elevation will be inhabited only during the summer months, and will require water service only during that portion of the year.

TECHNIQUES FOR DETERMINING LAND AREAS

Acreage included within the various types and classes of land and land use, as delineated on maps and aerial photographs, were obtained either by planimetering the delineated areas or by the cutting and weighing of maps. Generally, field delineations of land areas made on aerial photographs were transferred to a base map prior to measurement of areas. Planimetering of areas was done in cases where areas were measured directly on the aerial photographs, and, in some instances, for measuring small parcels of land delineated on maps.

Acreage determination by the cutting and weighing of maps was the method generally used for the present bulletin. In this method, a print of the area to be measured, together with a control of known area, is made on ozalid intermediate material, a high quality vellum paper of uniform weight. Land areas for which acreage is to be determined are cut from the print. All areas cut from the print, as well as the control, are weighed on a precision balance to the nearest one-tenth milligram and the gross area determined in accordance with the weight. Detailed cuttings are then made from the gross area, and separate weighings are made of subareas or groupings of subareas in accordance with the data desired. The control is also weighed intermittently during this process in order that changes in the moisture content of the vellum are accounted for in the computation and assemblage of acreages of the desired classification. Conversion of weights of land areas to actual acreages is made by multiplying the weights of individual areas, determined between weighings of the control, by the ratio of the control area to the average weight of the control at two successive weighings.

DETERMINATION OF UNIT VALUES OF WATER USE

Detailed investigations and studies were made to determine appropriate unit values for irrigation use of water throughout California, and for urban use of water in the three large metropolitan areas in and around San Francisco, Los Angeles, and San Diego. The unit values of urban water use in most of the remaining portions of the State were derived mainly from records of water agencies serving many of the smaller cities of the State. Unit values of water use used for other water service areas were generally based on records and estimates furnished by authoritative agencies.

Irrigation Water Use

A comprehensive study was made of available experimental data on consumptive use of irrigation water, existing records of irrigation deliveries, and return flows of water, as secured from irrigation districts and other public and private agencies. Investigation was also made of prevailing irrigation practices in the several parts of the State. The method which was developed for determining the unit values of consumptive use of irrigation water provided a workable standard for derivation of unit values over a wide range of climatic conditions. The method was generally applicable throughout California, and is referred to as the "general method" in this bulletin.

The specialized cultural and irrigation practices for a few crops, such as rice, winter-grown potatoes, and grain, appreciably influence the consumptive use of water by these crops. Cultural and irrigation practices for many crops grown in the Sacramento-San Joaquin Delta also differ considerably from those used to produce the same crops in other parts of the State, and affect unit values of consumptive use to such an extent that they could not be evaluated readily by the general method. For such exceptional situations of cultural and irrigation practice, unit values of water use by irrigated crops were derived by so-called "special methods" of analysis.

Largely on the basis of judgment, it was assumed for most of the State that the unit seasonal value of consumptive use of water applied to farm houses, outbuildings, and surrounding farm lots averages 0.5 foot of depth. The consumptive use of precipitation on such farm lots was estimated to be the same as that for native vegetation.

In many parts of California where climatic conditions permit, it is the practice to grow more than one irrigated crop on the same land in a single season. For such areas the unit values of consumptive use of water were adjusted to reflect the resultant increase in water use. In the methods later described, these increased unit values of consumptive use were computed by lengthening the crop-growing period to permit the maturing of the indicated number of irrigated crops.

Verification of the results obtained by the application of the derived unit values of consumptive use of water to a given pattern of land use was made by applying these unit values to actual crop patterns in those areas of California susceptible of complete hydrologic analysis. In these cases the total seasonal consumptive use of water during a mean period of water supply and climate, as derived by application of the computed unit values, compared favorably with the difference between the measured inflow and outflow of water in the test areas.

It is anticipated that the unit values of consumptive use of water estimated for this bulletin will be used in connection with long-range water resource planning. The values expressed, therefore, are those that would occur under mean conditions of water supply and climate, and represent the average consumptive use of water when an adequate water supply is available to produce optimum crop yields.

General Method. For most of California unit seasonal values of consumptive use of applied water and of precipitation for each of the irrigated crop groups were estimated by a method developed mainly by Harry F. Blaney and Wayne D. Criddle of the Soil Conservation Service of the United States Department of Agriculture. However, the basic method of these authorities was modified somewhat to meet the special needs of the present studies.

The general method expresses, by means of the formula $U = KF$, the relation between consumptive use of water, average temperature, and daylight hours in a given area. Consumptive use is established from experimental data or from measured values of use of water. Monthly average temperatures and monthly per cent of annual daylight hours are secured from published data from the U. S. Weather Bureau. Other factors, such as humidity, soil depth and quality, and wind movement, which are known to affect water use, are neglected in the correlation, due to the lack of adequate data except for a relatively few localities. The effects of these unevaluated items, however, are contained in the empirical coefficient "K."

The first step in the general method for estimating the seasonal consumptive use of water by each crop is to divide the season into two periods which are termed the "cultural period" and the "noncultural period." The former period varies with each crop, and generally comprises the irrigation season and the growing season of the crop. The noncultural period comprises the remainder of the season. Generally, during this latter period the annual crops have been removed and the land is without vegetation, although in many cases, preparation of the land for the next season is accomplished. Deciduous orchards and perennial forage crops in most areas are in a dormant stage during the noncultural period. Thus, the characteristics of consumptive use of water in a given locality are completely different in the cultural period from those in the noncultural period.

The consumptive use of water by a given crop in a given area during the cultural period is expressed in the formula $U = KF$, where:

U = consumptive use of water by the crop, in inches of depth

F = sum of the monthly consumptive use factors for the cultural period (sum of the products of mean monthly temperature and monthly per cent of annual daylight hours, or $t \times p$)

K = an empirical coefficient

t = mean monthly temperature, in degrees Fahrenheit

p = monthly total of daytime hours, expressed as a per cent of the total for the year

The "K" coefficient for each crop is derived by utilizing values of consumptive use of water from data obtained from tank experiments, measurements of field delivery of irrigation water, studies of inflow and outflow of water from irrigated areas, studies of soil moisture depletion on irrigated plots, and from estimates based on the experience and judgment of qualified experts. The "K" coefficient is determined by using consumptive use values, obtained as above, and corresponding values of the consumptive use factor, "F," in the basic formula.

For determination of variance in value of the "K" factor, the State was divided into 16 climatic areas, ranging from the low desert region of the Imperial Valley to the cool coastal lands of the northwestern coast. Within each climatic area, values of the "K" coefficient were computed by consideration of all available data pertaining to crops and use of water. The "K" coefficient for various crops was expressed as a percentage of the "K" coefficient for alfalfa in areas for which the greatest amount of data pertaining to these crops was available. The resulting percentage was applied to the "K" coefficient of alfalfa in order to estimate the "K" coefficient for various crops in areas where sufficient data were not available.

During the noncultural period the consumptive use of water in a given unit area is derived by application of appropriate unit consumptive use of water values, which are based on experimental and investigational data, experience, and judgment. The values used in the current investigation, within the limits of available precipitation were:

(a) 1 inch of depth of water per month for annual crops or for land without vegetation.

(b) 1.5 inches of depth of water per month for land devoted to orchards or vineyards.

(c) 2 inches of depth of water per month for forage or cover crops.

The total seasonal unit value of consumptive use of water, regardless of source of the water, is the sum of the values obtained from the two foregoing computations applicable to cultural and noncultural periods. To determine the seasonal unit value of consumptive use of applied water, that is, the water provided by means other than precipitation, an estimate of effective precipitation is necessary. Effective precipitation is that portion of precipitation that is consumptively used and does not run off or percolate to ground water. The difference between total seasonal unit value of consumptive use of water and seasonal effective precipitation is that portion of the seasonal consumptive use provided by application of water to the irrigated area. Effective precipitation is segregated into three portions for the purposes of evaluation:

(a) Precipitation occurring and consumptively used during the cultural period. In California this is generally minor in amount.

(b) Precipitation occurring during the noncultural period and consumptively used during that period. The amount is limited by the previously stated criteria governing consumptive use of water during this period.

(c) Precipitation occurring during the noncultural period and percolating to the root zone of the crop where it is retained for consumptive use during the following cultural period.

Computations of unit values of consumptive use of water on land devoted to irrigated cotton in the Central Valley of California, at latitude 36°, furnish an illustrative example of the general method. Values for mean monthly temperature and precipitation were assumed for purposes of this illustration. The empirical coefficient, "K," which was obtained from experimental data, was assumed to be 0.62. The cultural period used for cotton was April through October. In the noncultural period it was assumed that consumptive use of water is equal to all precipitation up to one inch of depth per month.

Special Methods. A description of the methods of derivation of unit values of consumptive use of water by those crops affected by specialized cultural and irrigation practices follows:

A. Rice. Irrigation practice in rice culture varies considerably from that followed in the production of other crops. Fields are kept flooded from the time

SAMPLE COMPUTATION OF UNIT VALUES OF CONSUMPTIVE USE OF APPLIED WATER FOR LAND CROPPED TO COTTON

Cultural Period

Month	Mean temperature, in degrees F. (t)	Percent of annual daylight hours (p)	Consumptive use factor ($t \times p$)	Mean precipitation, in inches of depth
April	60.5	8.86	5.36	1.00
May	67.5	9.83	6.64	0.55
June	74.7	9.84	7.35	0.10
July	81.0	10.00	8.10	0.02
August	79.1	9.41	7.44	0.01
September	72.9	8.36	6.09	0.14
October	64.2	7.84	5.03	0.53
TOTALS			46.01 = "F"	2.35

Consumptive use of water during the cultural period = $U = KF$ = $0.62 \times 46.01 = 28.51$ inches of depth

Noncultural Period

Month	Consumptive use of water, in inches of depth	Mean precipitation, in inches of depth
November	0.79	0.79
December	1.00	1.71
January	1.00	2.04
February	1.00	1.90
March	1.00	1.82
TOTALS	4.79	8.26

Consumptive use of water during the noncultural period = 4.79 inches of depth

Total seasonal consumptive use of water = $28.5 + 4.8 = 33.3$ inches of depth

Adjustments for Effective Precipitation

	Inches of depth	
Total seasonal precipitation		10.61
Deductions		
Precipitation occurring and consumptively used during cultural period	2.35	
Precipitation consumptively used during noncultural period	4.79	7.14
Precipitation occurring during noncultural period and retained in root zone for use by crop during cultural period*		3.47

* Available moisture-holding capacity in the root zone equals the depth of the principal root zone, estimated to be approximately 4 feet in this instance, multiplied by the unit moisture-holding capacity of the soil, estimated to be 1.5 inches per foot of depth, yielding a product of 6 inches of water depth in this example. Cultural practice of this crop permits the assumption that the entire root zone would be depleted of moisture prior to the beginning of the noncultural period. Thus, it was assumed that the 3.47 inches of precipitation available from the noncultural period was carried over into the cultural period as soil moisture in the root zone.

Determination of Seasonal Consumptive Use of Applied Water

	Inches of depth	
Total seasonal consumptive use of water		33.3
Deductions		
Precipitation occurring and consumptively used during cultural period	2.3	
Precipitation consumptively used during noncultural period	4.8	
Precipitation occurring during noncultural period and retained in root zone for use by crop during cultural period	3.5	10.6
Seasonal consumptive use of applied water		22.7

of planting to the time the crop matures, when fields are drained to enable harvesting the yield. Planting usually takes place between April 15 and May 15, the fields are drained the following September and harvested during October. The period used for determination of the consumptive use of applied water was the 5-month period from May through September.

The volume of irrigation water applied varies considerably and is dependent to a large extent upon soil type and availability of water. The gross amount of irrigation water applied is frequently greatly in excess of the consumptive use since the maintenance of a small flow in the ponds facilitates the control of fungus and water plants and enhances the crop yield. Existing cultural practices indicate that satisfactory yields are produced when the return flow, or difference between applied water and consumptive use of applied water, amounts to about one foot in depth on the cropped area.

Available data for rice farming areas in the Sacramento Valley indicate that the total water applied during the growing season amounts to about 5.4 feet in depth and that the return flow is about one foot in depth. Reliable estimates of deep percolation below the root zone indicate that about 0.3 foot of water is disposed of in this manner. The unit seasonal value of consumptive use of applied water is therefore about 4.1 feet in depth, and that value is used in estimates of water requirements for the present study.

The value of consumptive use of applied water, as determined above, applies principally to those areas in the Sacramento Valley for which data were available. For those areas, it was estimated that an average depth of 0.2 foot of rainfall occurs during the cultural period. For others areas where the precipitation differs significantly from the above value, the unit volume of consumptive use of applied water was adjusted accordingly.

Noncultural period consumptive use of water on rice land was estimated to amount to one inch of depth per month, when that amount of water is available. On the basis of an assumed 3-foot depth of principal root zone and 1.5-inch depth of effective moisture-holding capacity per foot of soil depth, it was estimated that 4.5 inches of soil moisture is retained from winter precipitation and carried over into the growing season, when it is consumptively used. These two items, plus the cultural period precipitation and consumptive use of applied water, were taken to equal the total seasonal consumptive use of water by rice lands.

B. Winter-grown Hay and Grains. Small grains, such as barley, oats, and wheat, threshed for grain or cut for hay, are grown extensively throughout California. Unit values of water use by irrigated crops of this type during the summer months were estimated by the previously described general method. Hay and grain crops, however, are also grown during winter months by specialized cultural practices. Experience indicates that, in general, when the depth of seasonal precipitation is approximately 17 inches or more, normally distributed throughout the season, these crops can be satisfactorily grown without irrigation. In some areas, however, precipitation is not sufficient for this purpose, and the available winter moisture must be supplied by irrigation. Winter-grown grain is planted in the fall, matures during the winter months, and is harvested in June and July.

By inspection of monthly precipitation records in a zone of 17-inch depth of mean rainfall, it was observed that the amount of precipitation falling during the months from November through April, the cultural period for winter hay and grain, averages about 15 inches of depth. It was assumed that all of this winter precipitation is consumptively used in maturing the crop, and that it is adequate in amount for that purpose. The remaining 2-inch depth of precipitation available was considered to be consumed by weed growth or evaporated from the soil during the noncultural period. It was further assumed that in areas where the normal seasonal depth of precipitation is less than 17 inches, the supplemental irrigation required for maturing winter-grown small grain and hay is measured by the difference between the actual November-through-April precipitation and a depth of 15 inches.

C. Winter-grown Potatoes. In the southern San Joaquin Valley the climatic conditions are such that potatoes can be grown during the winter months, thereby meeting favorable marketing conditions. Planting times vary with locality from late November through February, and the crops mature in May and June. Unit values of use of water by winter-grown potatoes were estimated from results of studies of prevailing cultural and irrigation practices.

The three months from March through May were taken as the average cultural period. A study of available data on water use for irrigation of potatoes indicated that an average depth of 30 inches of irrigation water is applied. Based upon the available information, it was estimated that the efficiency of such irrigation application averages approximately 50 per cent. Therefore, the seasonal depth of consumptive use of applied water for winter-grown potatoes, based upon these figures, was estimated to be 15 inches. The average depth of precipitation during the cultural period was estimated to be about 2 inches, all of which is estimated to be consumptively used. A depth of 17 inches, therefore, was taken as the total consumptive use of water during the three-month cultural period. Consumptive use of water during the remainder of the season was taken as equal to normal precipitation, all of which was assumed to evaporate from the soil or transpire and evaporate from weed growth.

D. Crops Produced in Sacramento-San Joaquin Delta. Unit values of consumptive use of water by crops grown in the Sacramento-San Joaquin Delta were based chiefly on data from experiments with growing vegetation in tanks in the delta area. These experiments were conducted by the United States Department of Agriculture in cooperation with state agencies, over a period of six years prior to 1931. A summary of the monthly and seasonal unit values was published in Bulletin No. 26, "Sacramento River Basin," Division of Water Resources, 1931.

In order to evaluate the seasonal depth of consumptive use of applied water in the Delta, estimates of the average depth of precipitation consumptively used were subtracted from the total seasonal unit values of consumptive use of water. All noncultural period consumptive use of water was assumed to be provided by precipitation, and all precipitation occurring during the cultural period was assumed to be consumptively used. The depth of precipitation carried over into the cultural period in the root zone was estimated to average approximately two inches per foot of soil depth.

The unit value of consumptive use of water by land in the Delta devoted to irrigated pasture was computed as previously set forth in the description of general methods followed in the remainder of the State.

Urban and Suburban Water Use

Unit values of water use in urban and suburban areas of California, other than in the San Francisco Bay Area and most of the South Coastal Area which are discussed in the following section, generally were estimated from records of present deliveries of water. Available data from private and public water service agencies were utilized in developing appropriate unit values of water use.

Although there are large variations in per capita water deliveries to various cities throughout the State, analysis of available records discloses no firm trends in the amount of the deliveries as related to metered or unmetered water service, or as related to costs of water to the consumer. More important factors in this respect seem to be the climatological characteristics of the several areas, the abundance or scarcity of water, and the nature and habits of the communities. For these reasons, unit values of water use based on recorded deliveries in cities generally were assigned to adjacent or nearby urban and suburban areas with similar water-using characteristics, where data on deliveries were not available.

Limited available information on the quantity of sewage outflow from urban and suburban areas indicated that, on the average, about 50 per cent of the water production for a city is discharged as sewage. It was assumed, therefore, that in the Central Valley and Lahontan Areas, urban and suburban consumptive use of applied water is equal to one-half of the quantity of water delivered to the area. In all other areas, sewage is generally discharged to the point of final disposal without opportunity for re-use. In these areas, the gross delivery was taken as both the consumptive use and the gross requirement for water in urban and suburban areas.

Past and present records of water deliveries to urban areas in California indicate that in recent years there has been an increase in per capita requirement for water, and that the trend is continuing. Part of this increase may be credited to more liberal use of water in households and gardens. In this connection a substantial part undoubtedly results from development of modern water-using household appliances, such as garbage disposal units and automatic washers. In some communities, also, an increasing industrialization has raised per capita values of water use. To account for this increasing use, the probable ultimate unit values of water deliveries to urban and suburban areas generally were increased 10 per cent over present values.

Use of Water in Metropolitan Areas

For the three major metropolitan areas of the State, in and around San Francisco, Los Angeles, and San Diego, as well as for most of the remaining urban areas in the South Coastal Area, unit values of water use by each of the principal types of urban land use were estimated by a sampling procedure. In this procedure, an inventory was made of measured water deliveries in sample areas representative of each urban type. For irrigated lands within the metropolitan areas the ''general method'' of determining unit values of consumptive use of water was employed.

Evaluation of unit water use by urban types in the foregoing areas was generally based on the assumption that water deliveries to urban consumers constitute an approximate equivalent measure of consumptive use of applied water. This follows from the fact that in most of the areas sewage is presently discharged to the ocean, and for purposes of inventory may be considered to be wasted or consumptively used. Exceptions to this general assumption were made in those unsewered absorptive portions of the South Coastal Area, where due allowance was taken of return flows from sewage.

In the sampling procedure, the sample areas selected usually consisted of single blocks or a number of contiguous blocks devoted to one type of land use, and chosen so as to be representative of conditions in the area. The total delivery of water to a given sample area for a recent year was determined by adding all the individual metered deliveries as obtained from records of the water agency serving the area. The net acreage of the sample area was determined from assessors' plats or other maps of suitable scale. The unit value of water delivery was obtained by dividing the total delivered water supply by the net area of the sampling, excluding streets.

The total acreage sampled for each type of land use varied with the indicated range of unit values of water delivery. Industrial deliveries of water varied so widely, depending upon the industry and the locale, that in order to obtain an average for all industries it was necessary to extend the sampling surveys to the larger areas devoted almost entirely to industry. These included the Vernon, Terminal Island, and other industrial areas near Los Angeles and the highly industrialized Emeryville area in Oakland. Additional extensive surveys were made to determine the unit value of water deliveries to each of a number of major industries throughout the San Francisco Bay and Los Angeles Areas.

Probable ultimate unit values of water deliveries in the metropolitan areas usually were estimated by adjusting the present unit values as determined by the sampling procedure. The adjustments were based, insofar as possible, upon indicated trends in unit water requirements for each of the different types of urban land use.

Use of Water in Other Water Service Areas

Estimates of unit values of water use in those present or future water service areas of California not classified as either irrigated, urban and suburban, or metropolitan, were based largely on records or estimates of present water delivery. By the nature of the activities involved, water utilization in most of the other water service areas is not adaptable to areal classification, and the unit values of water use consisted of per capita or unit of production values rather than as per acre values.

The United States Forest Service prepared estimates of unit values of water use for recreation, industries, grazing, pollution abatement, esthetics, etc., within the national forests. These values were based on measured deliveries of water in some instances, but to a large extent were estimated from experience and judgment. Similar estimates were prepared by the National Park Service and by the State Division of Beaches and Parks for areas under their respective jurisdictions.

Estimates of unit values of water use by permanent military establishments, when so classified, were based on records of water deliveries and populations of the establishments obtained from military authorities. The same values were utilized for both present and probable ultimate conditions.

Use of water in the lumber industry was estimated on the basis of units of production. Such use does not occur in all hydrographic areas of the State, and varies in amount in the areas in which it does occur. The principal purposes for which water is used in the heavily forested North Coastal Area are in the production of wood pulp products and in evaporation from mill ponds. Based on data available from the industry, the consumptive use of water in this area for these purposes is estimated to average about 25 acre-feet per million board feet of timber harvest.

The mining industry, while requiring an adequate supply of water in relatively isolated locations, generally has a minor consumptive use. Information on use of water by the industry is scant and the estimates in this bulletin are based on an assumed gross requirement in the various hydrographic areas. Much of the ore which is mined is transported to refineries located in or near urban centers, and the water requirements related to refining are included in the general industrial requirements for such urban areas. In the North Coastal Area, gold refining involves the use of about 1.5 acre-feet of water per ounce of gold produced, and this value was used in estimating requirements for other areas. Very little of this water is used consumptively, but the disposal of the highly toxic waste requires treatment to prevent stream pollution. For this reason, and because of the relatively minor amounts of water involved, the total use of water by the mining industry was treated as a consumptive use in the determination of ultimate water requirements.

A considerable amount of water has, in the past, been nonconsumptively used in the production of gold by hydraulic methods and by dredging. Restrictions now placed on such operations, in order to prevent stream pollution and destruction of land, indicate that in the future placer gold will be produced by less destructive methods and that smaller amounts of water will be required.

In general, the water consumed in the propagation and preservation of fish and wildlife is so minor in extent that the actual consumptive use was not computed. Minimum stream flow requirements for the protection of fish life at specified points on many streams of the State were estimated by the California Department of Fish and Game. These estimates are listed in Appendix F. Wildlife refuges on the valley floor of the Central Valley, and the Tule Lake, Lower Klamath Lake, and smaller refuges in other parts of the State use water consumptively in an amount equal to evaporation from the ponded areas established to attract game. In these cases, the evaporation was estimated from available data and was included in the water requirements of the hydrographic areas concerned.

As has been stated, it was assumed that all lands of the State will be included in one of the types of water service areas under conditions of probable ultimate development. In such water service areas outside of the previously described specific types of development, unit values of water use were expressed on a per capita basis, assumptions being made as to the densities of ultimate population in the various parts of the State. For those lands in the other water service areas above an elevation of 3,000 feet it was assumed that occupancy would be limited to a few months of the year, thus reducing the effective seasonal per capita value of water use. Corresponding lands below 3,000 feet in elevation were assumed to be occupied for longer periods of the year. Consumptive use of precipitation was not estimated for other water service areas since it was not considered as meeting any portion of the water requirements.

DETERMINATION OF WATER REQUIREMENTS

In general, the estimates of present and probable ultimate requirements for water were derived by applying unit values of water use to the areas of each type of land use and dividing by the appropriate efficiency factor. In some instances, requirements were separately determined and the resultant efficiencies estimated to the nearest five per cent. The amounts of most nonconsumptive requirements for water are not readily determined except as they relate to actual water development projects, and can be evaluated only with consideration to other requirements for water at the time future projects are implemented. For this reason, nonconsumptive water requirements are discussed only generally in this bulletin.

Present Requirements

The present irrigation requirement for water in each hydrographic unit was estimated as the sum of the products of the appropriate unit values of consumptive use of applied irrigation water and the areas of the various irrigated crop types, divided by an estimated water service area efficiency, or by equivalent procedure. Present urban and suburban water requirements within hydrographic units other than the South Coastal Area, were estimated as the product of a unit value of water delivery and the determined area of the urban and suburban land use. In the South Coastal Area the urban and suburban requirements were estimated by the procedure described in the next paragraph for metropolitan areas. For unclassified areas within hydrographic units throughout the State, present water requirements were estimated as the sum of the products of unit values of water delivery and population, units of production, and other appropriate factors. The total present requirement for water in each hydrographic unit was then taken as the sum of the individual requirements for the several classes of water use.

Present urban water requirements for hydrographic units of the metropolitan areas in and around San Francisco and San Diego were estimated as the sum of the products of appropriate unit values of water delivery times the areas of the various types of urban land use, multiplied by a factor to account for water losses in conveyance and delivery throughout the water system. Records indicate that such water losses generally vary from about 5 to 15 per cent of the production of the water service agency. However, in estimating urban requirements for hydrographic units of the remainder of the South Coastal Area, including the Los Angeles Metropolitan Area, consideration was given to re-use of a portion of the unconsumed delivered urban water in absorptive areas, including consideration of the status of sewage reclamation. Requirements for irrigation water in the metropolitan areas were estimated as described in the preceding paragraph.

Data were available in many hydrographic units regarding the irrigation efficiency attained by agencies serving portions of each unit. This efficiency was a principal factor in the estimation of water service area efficiencies for irrigated lands. The estimated consumptive use of applied irrigation water in individual areas was divided by the quantity of water delivered to those areas in order to provide an index by which the water service area efficiency of the unit could be estimated. In those hydrographic units where such data were available from several agencies, the water service area efficiency for irrigated lands was evaluated by consideration of the total data available. In units where this information was not available, water service area efficiencies as determined for other hydrographic units in the same general locality and with similar water-using characteristics were adjusted in accordance with experience and judgment. Determination of water service area efficiencies for irrigated lands included consideration of many pertinent factors, including: the amount of re-use of return flow from irrigation within the area, irrecoverable losses of water resulting from operation of the conveyance and distribution system, flushing water required to maintain proper salt balance in soils of the area, and topographic and geologic conditions which affect the use and application of irrigation water.

Ultimate Requirements

Estimates of water requirements under conditions of probable ultimate development were derived by methods generally similar to those employed for present conditions. The principal difference in the methods generally used in estimating the requirements for irrigated lands was the consideration given to geologic factors that will be of primary importance under conditions of complete irrigation development. These factors include the existence, extent, and type of ground water basins within a hydrographic unit, and their position with relation to sources of water supply for the unit and to other hydrographic units.

The first step in determination of the ultimate irrigation requirement for water in many hydrographic units was to divide the unit into subareas, largely on the basis of topographic and geologic conditions. Irrigable lands within these subareas were segregated, on the basis of geological conditions, into lands overlying free ground water basins and those overlying confined ground water basins or nonwater-bearing materials. In the former case, relatively high water service area efficiencies were assumed, while in the latter case the water service area efficiency was estimated to be somewhat lower. Consideration was given to available data and experience regarding irrigation practice in comparable existing fully developed irrigated areas in developing estimated ultimate efficiencies. For each hydrographic unit a weighted average water service area efficiency was then derived, on the basis of previously computed subarea efficiencies of the irrigated lands respectively overlying absorptive and nonabsorptive materials, and considering re-use of return flow from one subarea by another subarea which is topographically situated and geologically adapted to use of the return flow. Return flows of irrigation water were thus routed through the entire hydrographic unit to determine the requirement for irrigation water in the unit as a whole. The method was modified somewhat in detail in its application to hydrographic units of the South Coastal Area.

An extension of this method was employed in determination of the ultimate irrigation requirement for water in certain of the hydrographic units on the floor of the Central Valley where considerable information on irrigation water use and return flow is available. Nonabsorptive irrigated lands were divided topographically into two parts, the higher of which was assumed to receive water to meet its full irrigation requirement from either surface or ground water sources independent of return flow from within the nonabsorptive area. The lower portion of the nonabsorptive area was assumed to receive a portion of its irrigation water supply from return flow of applied water on the higher portion. The basis for determination of the degree to which return flow was utilized was the data on water use collected over the past quarter century in the Sacramento and lower San Joaquin Valleys.

In hydrographic units, other than those in the San Francisco Bay and South Coastal Areas, the probable ultimate urban and suburban water requirement was estimated as the sum of the products of unit values of water delivery applied to the forecast ultimate areas of the urban and suburban class of land use. Probable ultimate urban requirements for water in hydrographic units of the San Francisco Bay and South Coastal Areas, including the metropolitan areas, generally were estimated as the sum of the products of appropriate unit values of water delivery applied to projected ultimate areas of the several major classes of urban land use, adjusted to account for water losses in conveyance and distribution throughout the water system. In the South Coastal Area consideration was also given to re-use of water in minor unsewered areas overlying absorptive materials. Ultimate water requirements for the remaining lands of the State, other than those classified as irrigated or urban and suburban under ultimate conditions of development, were estimated by applying appropriate unit values of water delivery to the forecasted population, units of production, and other appropriate factors.

The total ultimate requirement for water in each hydrographic unit was then the sum of the individual requirements for the several classes of water use. Usable return flow of applied water was considered to be a part of the water supply available in evaluating total ultimate water requirements of the major hydrographic areas of the State.

PROBABLE ULTIMATE SUPPLEMENTAL WATER REQUIREMENTS

For the purposes of this bulletin, probable ultimate supplemental water requirements were evaluated as the difference between present and probable ultimate requirements for water, plus the present supplemental water requirement in those areas experiencing an existing deficiency. The possible additional yield of existing water supply development works over the present water requirement of the area served, was not credited to reduction of the ultimate supplemental water requirement, except for the developed water supplies allocated from the Friant-Kern, Madera, and Contra Costa Canals. The difficulties inherent in defining and determining accurately the amount of present surplus yield, and in allocating such surplus to specific water service areas prior to completion of a comprehensive ultimate plan for water supply development and utilization, made the extensive yield studies necessary infeasible in the present study.

Methods employed for estimating present and probable ultimate water requirements of hydrographic units have been described. In hydrographic units with a present deficiency in water supply development, standard procedures were utilized to evaluate the present safe yield.

In hydrographic units where all or a major part of the present water supply is obtained from surface reservoirs, it was necessary to make operation studies over a critically dry period of years in order to estimate safe yields. Adequate information as to these operation factors was frequently lacking and yield studies were based on fragmentary runoff data, reservoir inflow being estimated by correlation with recorded or estimated flow of other streams. In many hydrographic units, surface supplies, while adequate during the early portion of the irrigation season, decrease rapidly during the summer and are insufficient for present requirements in the latter part of the irrigation season. In many of these cases, stream flow records were not available and estimates of safe yield were based on runoff estimates made by correlation with flow of other streams.

In hydrographic units where all or a portion of the water supply is obtained from ground water basins, a complete hydrologic investigation is necessary to determine present safe ground water yield. Special investigations have been made in the past for only a limited number of ground water basins in California. Complete hydrologic studies for the others were beyond the scope of work for this bulletin. Determinations of safe ground water yield employed in estimating probable ultimate supplemental water requirements for this bulletin must, for this reason, be considered as reasonably approximate evaluations.

For the reasons stated, the available data upon which to base estimates of safe yield of the present water supply development were often inadequate, and the resulting estimates of present supplemental requirements are necessarily subject to a margin of error. Determinations of ultimate supplemental water requirements based thereon, however, are believed to be sufficiently reliable for their principal purpose, which is to develop sufficient information regarding surplus and deficiency in water supply in the various areas of California to permit development of The California Water Plan.

A necessary qualification in evaluating the estimated supplemental water requirement for a major hydrographic area, or for a stream basin within that area, is that the total supplemental requirement is not necessarily equal to the sum of the individual supplemental requirements of the included hydrographic units. This follows from the fact that there is usually opportunity for re-use of return flows from water applied on upstream hydrographic units, thus reducing the supplemental requirement for the major hydrographic area or stream basin taken as a whole.

DETERMINATION OF PROBABLE ULTIMATE WATER REQUIREMENT OF METROPOLITAN AREAS BY POPULATION-SATURATION METHOD

In the course of the current State-wide Water Resources Investigation it became evident that the estimates of probable ultimate water requirement in the San Francisco, Los Angeles, and San Diego Metropolitan Areas are of major significance in planning for comprehensive water resource development in California. For this reason, and in view of inadequacies inherent in any known method of forecasting ultimate conditions, a supplemental series of estimates of ultimate water requirements was made for the metropolitan areas. These estimates were to a large extent independent of those previously described which were based on the land use pattern and unit areal values of water use. The supplemental estimates involved forecasting the probable ultimate population, which was done on an area-saturation basis rather than on one of chronological extrapolation, and forecasting the ultimate per capita water use on the basis of studies of past and indicated future trends in the various classes of urban water use. The studies of ultimate water requirement by the population-saturation method were undertaken with the objective of evaluating in general terms the reasonableness of the forecasts by the land use method.

The first phase of the population-saturation method of estimating ultimate water requirements was to forecast the ultimate population of each metropolitan area. Basically, this was done by multiplying estimated net ultimate urban areas by estimated population density values. In the San Francisco and San Diego Metropolitan Areas the net ultimate urban area was defined as the total habitable area, as determined by the previously described land classification surveys, decreased by forecast residual agricultural areas, nonwater-using industrial areas, and by the areas of heavy industry. In the Los Angeles Metropolitan Area, however, the industrial land use was not separated from the other types, while agricultural use was only accounted for indirectly. The net ultimate urban area in the San Francisco and San Diego Metropolitan Areas was segregated between valley and mesa lands and foothill lands. In the Los Angeles Metropolitan Area this subdivision was omitted.

The second phase in the population-saturation method was to forecast the ultimate per capita delivery of water for the several classes of urban water use in each metropolitan area. This was accomplished by study of recent trends in per capita values of delivery of water. The per capita deliveries were then projected to their probable ultimate values on the basis of the present trends and considered assumptions as to the nature of future urban development.

The final phase in the method was to multiply the forecast ultimate population by the assumed per capita values of water delivery in the several classes of water use. The sum of the products was adjusted for conveyance and delivery losses, resulting in the estimated total ultimate urban water requirement for each metropolitan area.

A description of the population-saturation method as it was developed and applied in the San Francisco Metropolitan Area will serve to illustrate the basic procedures involved. The applications of the method in the Los Angeles and San Diego Metropolitan Areas varied from the described procedure in detail, partly because of differing characteristics of the areas, and partly because of simultaneous independent development of the procedures by different investigators in each of the areas.

In the San Francisco Metropolitan Area the ultimate habitable area in each county, obtained from the land classification survey, was segregated into those parts with a present high degree of development and those relatively undeveloped. This was accomplished on the basis of population densities in appropriate subdivisions. These subdivisions were formed by assembling groups of voting precincts or census tracts having similar and, insofar as possible, homogeneous characteristics as to classes of present land use, particularly with regard to the several residential types. Consideration was also given to commercial, municipal, and industrial classes of land use.

Aerial photographs of each subdivision in relatively highly developed areas were examined in detail, without regard to topography, to determine percentages of occupancy and vacancy in the area under consideration. Present effective population densities within the subdivisions were next estimated by dividing the aggregate population of each subdivision by the total area actually occupied.

The next step was to forecast the proportion of the area of each subdivision that will ultimately be occupied. In this step, consideration was given to the probable effects of topography on urban development, the present trend toward tract-type housing construction, and other pertinent factors. The areas to be occupied by nonwater-using activities and heavy industry were excluded. Segregation was also made between valley and mesa lands and foothill lands to obtain patterns characteristic of differing topographic conditions. The estimated ultimate population of each subdivision was obtained by applying effective population densities to the areas actually to be occupied by urban development. Over-all effective population density factors were determined separately for valley and mesa lands and for foothill lands. This was done by combining the ultimate population and area forecasts for the various subdivisions in accordance with their topographical classifications.

A determination was made for each county in the San Francisco Metropolitan Area of those portions of the present relatively undeveloped area which are suitable for future urban development. This was done by study of topographic maps on the basis of voting precincts, census tracts, or townships. The considerations involved included topographic conditions, relative isolation from present urban centers, and other pertinent factors. Areas ultimately to be devoted to agriculture and industry were excluded, and a division of the net urban area was made between valley and mesa lands and foothill lands. The over-all effective population density factors for balanced urban communities, determined as described in the preceding paragraph, were applied to the portions of each county determined to be suitable for future development. This resulted in forecasts of probable ultimate urban population for the relatively undeveloped portions of the various counties, which were added to the estimates derived for those portions of the counties at present relatively highly developed to arrive at the estimate of the total ultimate urban population for the San Francisco Metropolitan Area.

The estimate of probable ultimate per capita water use in the San Francisco Metropolitan Area was based largely on records of annual delivery of water to individual consumers by 10 major public and private water service agencies in the area over a period extending from 1940 through 1950. These data were differentiated by the agencies according to several classes of urban water use, including residential, commercial, municipal, and industrial. The standards of classification varied somewhat among the several agencies, and the records were reconciled as required to permit combining of the data from the different agencies. Consideration was given to the use of large amounts of water by certain industries utilizing privately developed supplies, in addition to the data obtained from the water service agencies. Estimates of the total population served by the respective water service agencies were made for years corresponding to the available data on water deliveries. The total annual use of water was divided by the corresponding total population served to estimate the per capita use of water for each class of urban water service. These annual values were plotted so as to define recent trends in per capita use of water.

The foregoing data indicated a fairly constant rate of per capita use of water with regard to commercial and municipal uses. In determining the probable ultimate water requirement for these two classes the indicated present values were used. A prominent upward trend was apparent in the per capita use of water for residential purposes. On this basis, a substantial increase over the present value was forecast for ultimate residential per capita use of water. While no significant trend in per capita industrial use of water was noted, on the basis of an indicated over-all present deficiency in the level of industrial production in California, and in the San Francisco Bay Area in particular, a substantial future increase in per capita industrial use of water was predicted.

The final step in the population-saturation method was to total the estimated values of ultimate annual per capita use of water for the several classes of urban water use, and to apply the total to the estimated ultimate urban population to obtain an estimate of total annual ultimate urban use of water in the metropolitan area. The estimate of total use of water was increased by a factor representing estimated distribution and transmission losses, based upon the experience of water service agencies in the San Francisco Bay Area. This final value derived was the estimate of probable ultimate annual urban water requirement for the San Francisco Metropolitan Area.

CHAPTER III

NORTH COASTAL AREA

The North Coastal Area, designated Area 1 on Plate 8, constitutes the northwestern portion of the State between latitudes 38° and 42° N. Its shape is roughly that of a triangle, the shorter leg lying along the Oregon border for about 180 miles on the north and the longer leg along the Pacific Ocean for some 270 miles on the west. Within its boundaries are the entire counties of Del Norte, Humboldt, Trinity, and Mendocino, and parts of Siskiyou, Modoc, Glenn, Lake, Sonoma, and Marin Counties. Among the principal incorporated cities are Santa Rosa, Eureka, Ukiah, Fort Bragg, Arcata, Healdsburg, and Yreka.

The topography of the North Coastal Area is characterized by a predominance of mountainous terrain, and nearly one-half of the area lies within national forest boundaries. The major portion of the national forest land lies in the Cascade Mountains, Coast Range, and Klamath Mountains north of Mendocino County.

In order to facilitate the present studies, the North Coastal Area was divided into 16 hydrographic units, which, with two exceptions, are identical with the drainage basins of the principal streams. Two basins, those of the Klamath and Eel Rivers, were divided into upstream and downstream hydrographic units, while the principal tributaries of these two streams were also considered as separate hydrographic units. The 16 hydrographic units and their areas are listed in Table 2 and their boundaries are shown on Plate 8. Table 3 lists the several counties lying wholly or partly within the North Coastal Area, together with their included acreages.

TABLE 2

AREAS OF HYDROGRAPHIC UNITS, NORTH COASTAL AREA

Hydrographic unit: Reference number	Hydrographic unit: Name	Acres
1	Tule Lake	1,544,000
2	Shasta Valley	508,000
3	Scott Valley	423,000
4	Upper Klamath	614,000
5	Trinity	1,897,000
6	Klamath	1,416,000
7	Rogue	107,000
8	Del Norte	456,000
9	Redwood Creek	191,000
10	Mad River	409,000
11	Upper Eel	1,976,000
12	Humboldt	565,000
13	Mattole	235,000
14	Mendocino Coast	1,037,000
15	Russian River	960,000
16	Bodega	165,000
	APPROXIMATE TOTAL	12,500,000

TABLE 3

AREAS OF COUNTIES WITHIN BOUNDARIES OF NORTH COASTAL AREA

County	Acres
Del Norte	700,000
Glenn	53,800
Humboldt	2,305,000
Lake	190,000
Marin	95,400
Mendocino	2,247,000
Modoc	753,000
Siskiyou	3,270,000
Sonoma	842,000
Trinity	2,047,000
APPROXIMATE TOTAL	12,500,000

Prevailing northwest winds with heavy fog and moderate temperatures are typical of climatic conditions along the northern coast of California. Inland portions of the North Coastal Area characteristically experience a wider temperature range and more moderate winds. Precipitation is principally in the form of rainfall, with substantial snow falling in only the higher elevations. The heaviest rainfall in the State occurs in Del Norte County, where a mean seasonal precipitation of about 75 inches of depth has been recorded near Crescent City, and average seasonal values as high as 100 inches have been estimated for locations in the Klamath Mountains. The record at Healdsburg in Sonoma County in the southern portion of the North Coastal Area indicates a seasonal mean depth of precipitation of about 40 inches. Precipitation inland from the coast is relatively high throughout most of the higher mountainous areas. However, lower rates are typical of the larger mountain valleys and of the northeastern plateau areas. The 17-year precipitation record at Tulelake in Modoc County indicates an average seasonal depth of only about 10 inches. Variation in precipitation from year to year is typified by the 58-year record at Eureka which has a seasonal average depth of 38.34 inches, a maximum of 74.10 inches, and a minimum of 20.72 inches. On the average, approximately 85 per cent of the seasonal rainfall in the North Coastal Area occurs in the months from December through April.

It is estimated that the mean seasonal natural runoff of streams of the North Coastal Area is about 28,900,000 acre-feet, or about 41 per cent of that for the entire State. The greatest single contribution to runoff of the area is made by the Klamath River with a drainage area of approximately 15,700 square miles, one-third of which lies in Oregon. The mean seasonal natural runoff of the Klamth River in California is estimated to be about 11,120,000 acre-feet, or some 38 per cent of the total of the North Coastal Area. Runoff from the coastal streams closely follows the rainfall pattern. Average monthly stream flow during the dry summer months of July, August, and September is less than one per cent of the seasonal total in all coastal streams except the Klamath and Smith Rivers, and in these rivers it is only slightly higher. Shasta and Scott Rivers, draining absorptive interior basins, maintain relatively greater summer flows, with about 15 per cent of the seasonal runoff occurring during the three named summer months.

As shown on Plate 4, a total of 18 valley fill areas, which may or may not constitute ground water basins, has been identified in the North Coastal Area. Appreciable development and utilization of ground water supplies is presently limited to those basins underlying Shasta, Scott, and Butte Valleys, Eel and Mad River deltas, three irrigated areas in the Russian River Basin, and the Dry Creek-Santa Rosa Plains area.

The population of the North Coastal Area has more than doubled in the last 50 years. The Counties of Del Norte, Humboldt, Mendocino, Siskiyou, Sonoma, and Trinity had an aggregate population of approximately 110,000 in 1900 and 257,000 in 1950, an increase of about 134 per cent. The populations of the principal urban centers, as shown in Table 4, have almost doubled between 1940 and 1950. It may be noted that recent growth in population of suburban areas of the larger communities has been proportionately greater than within the city limits.

TABLE 4

POPULATION OF PRINCIPAL URBAN CENTERS, NORTH COASTAL AREA

City	1940			1950		
	Within city limits	In suburbs	Total	Within city limits	In suburbs	Total
Santa Rosa	12,600	4,800	17,400	17,900	15,000	32,900
Eureka	17,100	2,400	19,500	23,100	5,100	28,200
Ukiah	3,700	3,900	7,600	6,100	7,500	13,600
Fort Bragg	3,200	1,300	4,500	3,800	5,600	9,400
Arcata	1,800	3,200	5,000	3,700	5,600	9,300
Healdsburg	2,500	0	2,500	3,300	1,700	5,000
Fortuna	1,400	900	2,300	1,800	2,800	4,600
Yreka	2,500	500	3,000	3,200	1,100	4,300

Lumbering is the outstanding industry in the North Coastal Area, with timber products in 1951 valued at an estimated $175,000,000. Agriculture, the principal water-using industry, is second in importance, with the annual production valued at $80,000,000 by the 1950 census. The majority of the crops are closely allied with the livestock industry, and alfalfa, pasture, hay, and grain predominate. Irrigated areas have increased from 56,000 acres in 1900 to 213,000 acres in 1953. Most of this increase has occurred within the past 20 years.

Mining operations provided the incentive for the original water developments in the North Coastal Area. Beginning in 1849-50, ditches were constructed in Shasta and Scott Valleys to divert water for mining purposes. The first recorded use of water for irrigation occurred in 1850 when one of the mining ditches in Shasta Valley was utilized to irrigate agricultural lands. Mining has gradually decreased in importance. At the present time it includes chromite operations at various locations in the Klamath Mountains and the Coast Range, minor mercury production at mines scattered from Sonoma County to the Oregon border, the extraction of pumice in the Glass Mountain area of Modoc County, the production of sand and gravel, and some mining of gold, silver, and manganese. Since about 1900 agriculture has become the principal water-using industry. Numerous private and cooperative irrigation developments were constructed, with water supplied by pumping from stream gravels or by direct surface diversion. Many of the larger units have since been reorganized under irrigation district laws.

Six present irrigation districts in the North Coastal Area had a total area in 1948 of 36,400 acres, of which 14,411 acres were reported to be under irrigation. Four districts, Montague, Scott Valley, Grenada, and Big Springs, were organized to take over existing irrigation works. Butte Valley and Potter Valley Irrigation Districts were formed to develop previously unirrigated lands.

In 1906 the United States Reclamation Service began construction of the first unit of the Klamath Project in California and Oregon. Drainage and irrigation of lands surrounding Tule and Lower Klamath Lakes have been continued since that time, until an area of 69,840 acres in California was under irrigation in 1953 within the Klamath Project area.

Irrigation from surface storage in the North Coastal Area is accomplished by three large developments and numerous small reservoirs. Clear Lake Reservoir, conceived primarily as a flood control basin, also supplies water to a portion of the Klamath Project of the Bureau of Reclamation. Dwinnell Reservoir in Shasta Valley provides water for the Montague Water Conservation District. The Potter Valley Irrigation District utilizes Eel River water, stored in Lake Pillsbury and imported to the Russian River watershed primarily for power generation. After passing through the Pacific Gas and Electric Company power plant, the water is diverted for irrigation purposes in Potter Valley. Small water storage developments serve individual farms and ranches, lumber mills, and mines.

Fishing Fleet at Eureka

Courtesy Eureko Chamber of Commerce

Sawmill in North Coastal Area

Courtesy Eureko Chomber of Commerce

The large available runoff and rugged topography of the North Coastal Area provide conditions favorable to power generation, but present development in the area consists of only six hydroelectric installations, three of which are under 5,000 kilowatt capacity. This is due to the relatively small industrial and urban power demand within the area and the long transmission distance to urban load centers.

Municipal water supplies of the Cities of Eureka and Arcata are provided by reservoir storage and ground water pumping. Other communities are served by wells, springs, surface diversions, or combinations of these sources. A compilation of the principal water service agencies in the North Coastal Area is included in Appendix B, together with the number of domestic services and area of irrigated lands served by each agency.

The lumber industry has developed as the principal source of income in the North Coastal Area, mainly as a result of the large stand of virgin timber located within its boundaries. Other industrial development, such as food processing and the manufacture of plywood and furniture, are related to the area's primary industries, agriculture and forestry. The limiting influences of soils, topography, and short growing season have maintained relatively stable crop patterns in the North Coastal Area, with increases in production resulting from irrigation of previously dry-farmed lands. All irrigable land is expected to be developed under ultimate conditions to the same type of crop pattern as at present. Urban areas have developed slowly in the past due to lack of demand for urban services. Much of the recent growth of the larger urban centers has been in suburban areas surrounding existing towns, and growth in many cases has been at the expense of developed agricultural land.

The North Coastal Area has a high potential as a recreational area. The vast forested mountain areas, long scenic coast, and the abundance of fish and game make the area an important resort and recreational region. Development of recreational facilities has been greatest in the coastal redwood region and along the lower reaches of the Russian River, largely as a result of close proximity to the densely populated San Francisco Bay Area. The many streams of the North Coastal Area attract sport fishermen from throughout the State, and the coastal waters support an important sport and commercial fishery. As the population of the State increases, it is anticipated that an increasing demand will be placed upon the recreational facilities of the region. The North Coastal Area is well provided with the resources required to meet this demand, and it is anticipated that the resort and tourist trade will become a major field for development in the future.

The principal existing use of water in the North Coastal Area is for agriculture. Use of water for domestic, industrial, and power generation purposes is relatively minor. Ultimate demands for water within the area are expected to follow generally this same pattern, with estimated ultimate development predicated upon a continued predominantly agricultural and lumber economy.

High peak flood flows in an area of low population density and relatively sparse agricultural development have made flood control measures in the North Coastal Area difficult of justification, although widespread flooding of towns and agricultural lands has occurred periodically. It is probable that in the future adequate flood control works will be constructed in the areas of greatest development.

Use of water for recreation is limited to that consumed for domestic purposes in resort and recreational areas, evaporation from migratory waterfowl refuges, and to water used for supporting stream flows for maintenance of fish life. These uses will increase as facilities are developed to provide for the recreational needs of the growing population of the State.

Available data and estimates pertinent to the nature and extent of water requirements in the North Coastal Area, both at the present time and under conditions of probable ultimate development, are presented in the following portion of this chapter.

PRESENT WATER SERVICE AREAS

As a first step in estimating the amount of the water requirement in the North Coastal Area, with the present pattern of land use and under mean conditions of water supply and climate, determinations were made of the location, nature, and extent of irrigated and urban and suburban water service areas. Remaining lands were not classified in detail with regard to their relatively minor miscellaneous types of water service, although such water service was given consideration in estimating the present water requirement.

Irrigated Lands

It was determined that under present conditions of development in the North Coastal Area, about 213,000 acres are irrigated in a given year, on the average. This constitutes approximately three per cent of the land irrigated throughout California.

Grain and the forage crops, such as pasture, alfalfa, and hay, are the dominant crops due to their adaptability to the soils and the short growing seasons occurring throughout most of the area. Truck and orchard crops are produced throughout the region, but principally in small quantities for home consumption. Although a substantial acreage is planted to vines, this crop is principally dry-farmed. Lands in the Tule Lake and Butte Valley Basins produce quantities of truck, of which potatoes are the principal commodity. In the Tule Lake hydrographic unit potatoes were

The Klamath River

Courtesy State Division of Highways

Recreation in North Coastal Area

Courtesy Moulin Studios

classified separately so as to permit consideration of their somewhat higher water requirements. Crops in the Russian River Valley are more diversified, with pasture, field crops, orchard, and alfalfa constituting the bulk of the irrigated agricultural production.

The field surveys upon which determinations of irrigated acreage in the North Coastal Area were based were accomplished during the period from 1947 through 1953 by several agencies with varying standards and degrees of accuracy. Information regarding the dates of field mapping and sources of data is contained in Appendix D. Based on the available survey data, the irrigated lands were classified into various crop groups with a view to segregating those of similar water use. A list of these groups follows:

Alfalfa ---------- Hay, seed, and pasture.

Pasture --------- Grasses and legumes, other than alfalfa, used for livestock forage.

Orchard --------- Deciduous fruits and nuts.

Vineyard--------- All varieties of grapes.

Hay and grain--- The cereal grasses, wheat, barley, oats, and rye, harvested either as a hay or a seed crop.

Truck crops ----- Intensively cultivated fresh vegetables, including tomatoes, peas, corn, carrots, potatoes, squash, bushberries, flower seeds, and nursery crops.

Miscellaneous field crops------ Hops, field corn, and sugar beets.

It is estimated that approximately 4,100 acres in the North Coastal Area are occupied by farm lots at the present time. These consist of farm buildings and the immediately surrounding areas receiving water service.

Summaries of presently irrigated acreages within the North Coastal Area by the various crop groups are presented in Tables 5 and 6. Table 5 lists the acreages by hydrographic units, and Table 6 by counties.

Urban and Suburban Water Service Areas

It was determined that under present conditions of development in the North Coastal Area approximately 18,500 acres are devoted to urban and suburban types of land use. For the most part, business, commercial, and industrial establishments and surrounding homes included in this areal classification receive a municipal type of water supply. Areas of urban and suburban water service within each hydrographic unit of the North Coastal Area are listed in Table 7, and within each county in Table 8. It should be noted that areas shown are gross acreages, as they include streets and intermingled undeveloped lands that are a part of the urban type of community.

Unclassified Areas

As has been stated, remaining lands in the North Coastal Area, other than those that are irrigated or urban and suburban in character, were not classified in detail with regard to present water service. However, of a total of about 12,250,000 acres of such remaining lands, less than 20,000 acres actually receive water service at the present time. These relatively minor service areas consist of scattered developments in national forests and monuments, public beaches

TABLE 5

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, NORTH COASTAL AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Improved pasture*	Marginal pasture*	Meadowland*	Orchard	Truck crops	Hay and grain	Miscellaneous field crops	Net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
1	Tule Lake	6,900	0	7,400	8,200	10,700	0	14,800	57,300	0	106,000	2,200	3,300	111,000
2	Shasta Valley	10,600	0	13,900	7,700	4,100	0	0	1,300	0	37,600	800	1,200	39,600
3	Scott Valley	4,200	0	9,400	2,100	8,200	0	0	6,900	0	30,800	600	1,000	32,400
4	Upper Klamath	800	0	1,200	1,600	200	0	0	800	0	4,600	100	100	4,800
5	Trinity	200	0	2,600	600	0	0	0	0	0	3,400	100	100	3,600
6	Klamath	100	0	600	0	400	100	0	0	0	1,200	0	100	1,300
7	Rogue	0	100	0	0	0	0	0	0	0	100	0	0	100
8	Del Norte	0	1,600	0	0	0	0	100	0	0	1,700	0	100	1,800
9	Redwood Creek	0	600	0	0	0	0	200	0	0	800	0	0	800
10	Mad River	0	1,300	0	0	0	0	100	0	0	1,400	0	0	1,400
11	Upper Eel	300	700	0	0	0	0	0	100	0	1,100	0	0	1,100
12	Humboldt	400	9,300	0	0	0	0	0	800	0	10,500	100	200	10,800
13	Mattole	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Mendocino Coast	100	200	0	0	0	0	0	0	0	300	0	0	300
15	Russian River	800	4,800	0	0	0	2,700	400	300	4,300	13,300	200	300	13,800
16	Bodega	0	0	0	0	0	0	400	0	100	500	0	0	500
	APPROXIMATE TOTALS	24,400	18,600	35,100	20,200	23,600	2,800	16,000	67,500	4,400	213,000	4,100	6,400	223,000

* Detailed land use survey data from Klamath River Basin Investigation conducted by the State Division of Water Resources.

TABLE 6

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN COUNTIES, NORTH COASTAL AREA

(In acres)

County	Alfalfa	Pasture	Orchard	Truck crops	Hay and grain	Miscellaneous field crops	Net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
Del Norte	0	2,000	0	200	0	0	2,200	0	0	2,200
Humboldt	700	11,700	0	300	1,000	0	13,700	100	300	14,100
Mendocino	800	3,300	1,800	100	300	1,000	7,300	100	200	7,600
Modoc	3,300	10,900	0	8,500	20,400	0	43,100	900	1,400	45,400
Siskiyou	19,300	64,500	100	6,200	45,800	0	136,000	2,800	4,300	143,000
Sonoma	100	2,000	900	700	0	3,400	7,100	100	100	7,300
Trinity	200	3,100	0	0	0	0	3,300	100	100	3,500
APPROXIMATE TOTALS	24,400	97,500	2,800	16,000	67,500	4,400	213,000	4,100	6,400	223,000

and parks, private recreational areas, wild fowl refuges, and other similar recreational activities.

Approximately 46 per cent of the North Coastal Area lies within the boundaries of the Modoc, Klamath, Trinity, Shasta, Mendocino, and Six Rivers National Forests. The topography of most of these lands is rough, and the existing development is limited, in general, to timber production and stock grazing. Many small scattered valleys and plateaus in the area are suitable for the production of forage crops. The United States Forest Service reports a total of 18,800 acres of such lands under irrigation, and this acreage has been included in Tables 5 and 6. Other water service areas in the national forests are those occupied by administration buildings, public camps, picnic grounds, and other tourist accommodations, the total of which contributes only a small part to the total water service area. Historic monuments, and public beaches and parks, all administered by the California Department of Natural Resources, provide additional attractions and conveniences to vacationists who annually visit the natural scenic wonders of the North Coastal Area. There are 24 such recreational areas, covering a total of 53,800 acres, along the coast between Sonoma and Del Norte Counties. Water service requirements are minor, consisting of domestic supplies to permanently inhabited areas and summer supplies to camp and picnic areas. Similar service is supplied to Lava Beds National Monument, which includes 46,000 acres in Modoc County, and is under the jurisdiction of the National Park Service. Private recreational areas are scattered throughout the North Coastal Area, with the major developments of this type concentrated along the Russian River in Sonoma County.

Summary

Table 7 comprises a summary of present water service areas within hydrographic units of the North Coastal Area, segregated into irrigated and urban and suburban lands. A similar summary by counties is presented in Table 8.

PROBABLE ULTIMATE WATER SERVICE AREAS

In order to estimate the amount of water that will be utilized in the North Coastal Area with ultimate land use and under mean conditions of water supply and climate, projections were made to determine the probable ultimate irrigated and urban and suburban water service areas. It was assumed that the remaining lands, for convenience referred to as "other water service areas," ultimately will be served with water commensurate with their needs.

Irrigated Lands

Based on data from land classification surveys, it was estimated that a gross area of approximately 1,058,000 acres in the North Coastal Area is suitable for irrigated agriculture. Other than farm lots and

TABLE 7

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS, NORTH COASTAL AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands	Urban and suburban areas	Approximate total
1	Tule Lake	111,000	1,000	112,000
2	Shasta Valley	39,600	1,400	41,000
3	Scott Valley	32,400	200	32,600
4	Upper Klamath	4,800	200	5,000
5	Trinity	3,600	1,000	4,600
6	Klamath	1,300	400	1,700
7	Rogue	100	0	100
8	Del Norte	1,800	1,300	3,100
9	Redwood Creek	800	100	900
10	Mad River	1,400	800	2,200
11	Upper Eel	1,100	900	2,000
12	Humboldt	10,800	4,300	15,100
13	Mattole	0	0	0
14	Mendocino Coast	300	1,100	1,400
15	Russian River	13,800	5,600	19,400
16	Bodega	500	200	700
	Subtotals	223,000	18,500	242,000
	Unclassified areas receiving water service			19,500
	APPROXIMATE TOTAL			261,000

TABLE 8

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN COUNTIES, NORTH COASTAL AREA

(In acres)

County	Irrigated lands	Urban and suburban areas	Approximate total
Del Norte	2,200	1,400	3,600
Humboldt	14,100	5,900	20,000
Marin	0	100	100
Mendocino	7,600	2,200	9,800
Modoc	45,500	0	45,500
Siskiyou	143,000	3,000	146,000
Sonoma	7,300	4,900	12,200
Trinity	3,500	1,000	4,500
Subtotals	223,000	18,500	242,000
Unclassified areas receiving water service			19,500
APPROXIMATE TOTAL			261,000

TABLE 9

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, NORTH COASTAL AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
1	Tule Lake	276,000	4,600	50,200	221,000
2	Shasta Valley	144,000	2,100	34,200	107,000
3	Scott Valley	68,700	1,100	12,500	55,100
4	Upper Klamath	21,300	300	6,700	14,300
5	Trinity	22,600	300	5,500	16,800
6	Klamath	8,000	100	1,500	6,400
7	Rogue	600	0	100	500
8	Del Norte	30,500	300	3,700	26,500
9	Redwood Creek	2,200	0	400	1,800
10	Mad River	29,900	300	3,800	25,800
11	Upper Eel	49,900	700	6,200	43,000
12	Humboldt	75,000	700	9,000	65,300
13	Mattole	4,500	0	600	3,900
14	Mendocino Coast	75,800	900	10,500	64,400
15	Russian River	208,000	2,800	24,200	181,000
16	Bodega	41,400	500	5,300	35,600
	APPROXIMATE TOTALS	1,058,000	14,700	174,000	869,000

TABLE 10

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN COUNTIES, NORTH COASTAL AREA

(In acres)

County	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
Del Norte	35,000	300	3,500	31,200
Humboldt	126,000	1,500	16,400	108,000
Marin	14,700	100	8,100	6,500
Mendocino	155,000	1,400	34,900	119,000
Modoc	63,700	1,100	7,100	55,500
Siskiyou	450,000	7,100	97,500	346,000
Sonoma	195,000	2,900	2,300	190,000
Trinity	17,900	300	4,600	13,000
APPROXIMATE TOTALS	1,058,000	14,700	174,000	869,000

certain lands within the gross irrigable area that experience indicates will never be served with water, such as lands occupied by roads, railroads, etc., it was estimated that under ultimate conditions of development a net area of approximately 869,000 acres will actually be irrigated. Table 9 presents these estimates for hydrographic units of the North Coastal Area, and Table 10 for the various counties.

The probable ultimate crop pattern for irrigated lands of the North Coastal Area is presented in Table 11. The crop grouping parallels that used in the case of present development except for the added group titled "Vineyard." Since most present vineyards are dry-farmed, this group was of minor importance and not segregated in the case of the present irrigated crop pattern. It is expected to be of greater significance in the future.

Urban and Suburban Water Service Areas

It is expected that in the North Coastal Area urban and suburban growth generally will be associated with further development of agriculture, although the tourist trade and scenic attractions will probably influence growth of certain population centers. Increase of population may also be brought about by expansion of present and new industries, particularly those associated with the timber resource. It was estimated that under ultimate conditions of development urban and suburban water service areas will increase to about 53,000 acres. Urban and suburban types of land use are expected to occupy the same localities as at present, but vacant lands will be filled and densities increased. Additionally, it is probable that encroachment will occur on surrounding lands in an estimated amount of about 34,500 acres. For the purposes of the present studies no attempt was made to delineate the boundaries of such encroachment, nor to determine what proportion will be on irrigable lands. The estimate of probable ultimate urban and suburban water service areas is included in Table 13. It should be noted that the areas shown are gross acreages, including streets, vacancies, etc.

Other Water Service Areas

Remaining lands of the North Coastal Area, not classified as irrigable or urban and suburban under conditions of ultimate development, aggregate about 11,390,000 acres, or 93 per cent of the area. As previously mentioned, it was assumed that ultimately these lands will be served with water in amounts sufficient for their needs. No attempt was made to segregate these "other water service areas" in detail with regard to the nature of their probable ultimate water service. However, as shown in Table 12, they were

TABLE 11

PROBABLE ULTIMATE PATTERN OF IRRIGATED CROPS, NORTH COASTAL AREA

(In acres)

Hydrographic unit		Alfalfa	Pasture	Improved pasture*	Marginal pasture*	Meadow-land*	Orchard	Vine-yard	Truck crops	Hay and grain	Miscel-laneous field crops	Approxi-mate total
Refer-ence num-ber	Name											
1	Tule Lake	40,500	0	25,000	2,200	15,700	0	0	35,000	80,500	22,300	221,000
2	Shasta Valley	44,100	0	28,800	2,200	10,200	0	0	2,200	15,100	4,800	107,000
3	Scott Valley	16,700	0	13,700	5,000	6,900	0	0	400	11,800	600	55,100
4	Upper Klamath	3,700	0	5,200	3,100	0	100	0	100	1,800	300	14,300
5	Trinity	3,800	0	8,200	2,000	0	500	0	400	1,700	200	16,800
6	Klamath	1,100	0	3,600	300	300	200	0	400	500	0	6,400
7	Rogue	0	500	0	0	0	0	0	0	0	0	500
8	Del Norte	0	25,200	0	0	0	0	0	1,300	0	0	26,500
9	Redwood Creek	0	1,800	0	0	0	0	0	0	0	0	1,800
10	Mad River	1,500	18,000	0	0	0	1,000	0	0	5,300	0	25,800
11	Upper Eel	2,500	9,100	0	0	0	7,000	4,400	0	20,000	0	43,000
12	Humboldt	4,500	49,800	0	0	0	500	0	0	10,500	0	65,300
13	Mattole	0	3,500	0	0	0	0	0	0	400	0	3,900
14	Mendocino Coast	0	20,000	0	0	0	0	0	3,000	41,400	0	64,400
15	Russian River	5,000	45,000	0	0	0	18,300	12,500	4,000	90,300	6,000	181,000
16	Bodega	500	11,600	0	0	0	500	0	5,000	18,000	0	35,600
	APPROXIMATE TOTALS	124,000	185,000	84,500	14,800	33,100	28,100	16,900	51,800	297,000	34,200	869,000

* Detailed land use survey data from Klamath River Basin Investigation conducted by State Division of Water Resources.

TABLE 12

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, NORTH COASTAL AREA

(In acres)

Hydrographic unit		Inside national forests and monuments		Outside national forests and monuments		Approximate total
Reference number	Name	Above 3,000-foot elevation	Below 3,000-foot elevation	Above 3,000-foot elevation	Below 3,000-foot elevation	
1	Tule Lake	961,000	0	296,000	9,000	1,266,000
2	Shasta Valley	122,000	0	198,000	41,400	362,000
3	Scott Valley	137,000	0	213,000	3,800	354,000
4	Upper Klamath	229,000	184,000	105,000	74,200	592,000
5	Trinity	1,171,000	495,000	91,600	113,000	1,871,000
6	Klamath	810,000	368,000	16,300	210,000	1,404,000
7	Rogue	77,000	21,700	0	7,800	106,000
8	Del Norte	101,000	246,000	300	75,300	422,000
9	Redwood Creek	2,700	2,300	21,300	163,000	189,000
10	Mad River	107,000	29,200	28,100	213,000	377,000
11	Upper Eel	473,000	178,000	154,000	1,118,000	1,923,000
12	Humboldt	43,800	8,900	33,900	390,000	477,000
13	Mattole	0	0	2,700	227,000	230,000
14	Mendocino Coast	0	0	500	958,000	958,000
15	Russian River	0	0	13,300	723,000	736,000
16	Bodega	0	0	0	123,000	123,000
	APPROXIMATE TOTALS	4,234,000	1,533,000	1,174,000	4,449,000	11,390,000

broken down for convenience in estimating water requirements into those portions inside and outside of national forests and monuments, and further segregated to areas above and below an elevation of 3,000 feet. The lands classified as "other water service areas" include recreational developments, both public and private, residential and industrial types of land use outside of urban communities, wild fowl refuges, etc. By far the greater portion of the lands are situated in rough mountainous terrain, much of which is presently unaccessible. It is expected that even under conditions of ultimate development this portion will be only sparsely settled and will have only very minor requirements for water service.

Summary

Table 13 comprises a summary of probable ultimate water service areas, segregated into irrigated lands, urban and suburban areas, and other water service areas.

UNIT VALUES OF WATER USE

Recent investigation of the water resources of the Klamath River Basin provided much of the data used in estimating unit values of water use in the North Coastal Area. These data were modified by standard methods to provide complete coverage of the area.

TABLE 13

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS, NORTH COASTAL AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigable lands	Urban and suburban areas	Other water service areas	Approximate total
1	Tule Lake	276,000	1,700	1,266,000	1,544,000
2	Shasta Valley	144,000	2,100	362,000	508,000
3	Scott Valley	68,700	400	354,000	423,000
4	Upper Klamath	21,300	500	592,000	614,000
5	Trinity	22,600	3,300	1,871,000	1,897,000
6	Klamath	8,000	3,700	1,404,000	1,416,000
7	Rogue	600	0	106,000	107,000
8	Del Norte	30,500	3,200	422,000	456,000
9	Redwood Creek	2,200	300	189,000	191,000
10	Mad River	29,900	2,300	377,000	409,000
11	Upper Eel	49,900	2,700	1,923,000	1,976,000
12	Humboldt	75,000	13,300	477,000	565,000
13	Mattole	4,500	0	230,000	235,000
14	Mendocino Coast	75,800	3,000	958,000	1,037,000
15	Russian River	208,000	16,000	736,000	960,000
16	Bodega	41,400	500	123,000	165,000
	APPROXIMATE TOTALS	1,058,000	53,000	11,390,000	12,500,000

Irrigation Water Use

In general, unit seasonal values of consumptive use of water on lands devoted to the various irrigated crops were computed by the methods outlined in Chapter II. Soil moisture studies conducted in Shasta, Scott, and Butte Valleys resulted in more accurate values of consumptive use in these areas. Pasture lands of the Klamath River drainage basin were segregated into meadow, improved pasture, and marginal pasture. Unit water use values presented in this chapter are for improved pasture, while 25 per cent higher use was assumed to occur on meadowlands and 25 per cent lower use was estimated for marginal pasture lands.

Significant climatic variations, as related to consumptive use of water, occur among the hydrographic units of the North Coastal Area. For example, prevailing fogs and cool temperatures along the coast tend to reduce the consumptive use, and values for those areas affected were adjusted accordingly. Table 14 presents the estimated unit values of mean seasonal consumptive use of applied irrigation water and of precipitation on lands devoted to crops of the various groups.

Unit mean seasonal consumptive use of applied water on farm lots was estimated to be about 0.5 foot in depth in the southerly portion and 1.0 foot in depth in the northerly part of the North Coastal Area. Estimates of unit mean seasonal consumptive use of precipitation on farm lots varied from 1.1 to 2.2 feet in the various hydrographic units, and averaged about 1.7 feet of depth. These estimates were employed for both present and probable ultimate conditions of development.

Urban and Suburban Water Use

Present unit seasonal values of use of water on urban and suburban water service areas of the North

TABLE 14

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, NORTH COASTAL AREA

(In feet of depth)

Hydrographic unit		Alfalfa			Pasture			Orchard			Vineyard		
Reference number	Name	Applied water	Precipitation	Total	Applied water*	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Tule Lake	1.6	0.9	2.5	1.9	0.9	2.8	1.0	1.0	2.0			
2	Shasta Valley	1.8	1.1	2.9	2.2	1.0	3.2	1.4	1.1	2.5	----	----	----
3	Scott Valley	1.5	1.3	2.8	1.9	1.2	3.1	1.1	1.4	2.5	0.6	1.5	2.1
4	Upper Klamath	1.5	1.6	3.1	1.9	1.5	3.4	1.1	1.7	2.8	0.7	1.3	2.0
5	Trinity	1.6	1.5	3.1	2.0	1.4	3.4	1.2	1.7	2.9			
6	Klamath	1.5	1.6	3.1	1.9	1.5	3.4	1.1	1.7	2.8	----	----	----
7	Rogue	----	----	----	1.4	2.2	3.6				----	----	----
8	Del Norte	----	----	----	0.9	2.2	3.1	----	----	----	----	----	----
9	Redwood Creek	----	----	----	1.3	2.0	3.3	----	----	----	----	----	----
10	Mad River	1.3	2.0	3.3	1.5	1.8	3.3	0.7	1.8	2.5			
11	Upper Eel	2.0	1.8	3.8	2.4	1.4	3.8	1.3	1.6	2.9	0.9	1.2	2.1
12	Humboldt	1.3	1.9	3.2	1.6	1.6	3.2	0.7	1.7	2.4			
13	Mattole	----	----	----	1.4	2.0	3.4	----	----	----	----	----	----
14	Mendocino Coast	1.1	2.0	3.1	1.3	1.8	3.1	----	----	----	----	----	----
15	Russian River	1.9	1.7	3.6	2.1	1.5	3.6	1.2	1.5	2.7	0.8	1.4	2.2
16	Bodega	1.9	1.7	3.6	2.2	1.4	3.6	1.2	1.5	2.7	----	----	----

* Within the Klamath River Drainage Basin Pasture was segregated into three classes. The value shown in this table applies to Improved Pasture, while a 25 per cent lower value was assumed for Marginal Pasture, and a 25 per cent higher value was estimated for Meadowland.

TABLE 14—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, NORTH COASTAL AREA

(In feet of depth)

Hydrographic unit		Truck crops			Miscellaneous field crops			Hay and grain		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Tule Lake	1.2	0.9	2.1	0.9	0.9	1.8	0.9	0.9	1.8
2	Shasta Valley	1.3	0.8	2.1	0.9	1.0	1.9	0.9	1.0	1.9
3	Scott Valley	1.1	0.9	2.0	0.7	1.2	1.9	0.7	1.2	1.9
4	Upper Klamath	1.2	1.0	2.2	0.8	1.2	2.0	0.8	1.2	2.0
5	Trinity	1.3	1.0	2.3	0.9	1.1	2.0	0.8	1.1	1.9
6	Klamath	1.2	1.0	2.2	0.8	1.2	2.0	0.8	1.2	2.0
7	Rogue	-	-	-	-	-	-	-	-	-
8	Del Norte	0.2	1.5	1.7	-	-	-	-	-	-
9	Redwood Creek	0.3	1.4	1.7	-	-	-	-	-	-
10	Mad River	0.4	1.3	1.7	-	-	-	0.5	1.3	1.8
11	Upper Eel	-	-	-	-	-	-	0.8	1.2	2.0
12	Humboldt	-	-	-	-	-	-	0.5	1.2	1.7
13	Mattole	-	-	-	-	-	-	0.5	1.4	1.9
14	Mendocino Coast	0.4	1.3	1.7	-	-	-	0.5	1.3	1.8
15	Russian River	0.7	1.1	1.8	0.8	1.1	1.9	0.7	1.1	1.8
16	Bodega	0.7	1.1	1.8	0.8	1.1	1.9	0.7	1.1	1.8

Coastal Area were estimated largely on the basis of population. Available records of delivery of water to the areas, as compiled by municipalities and other public water service agencies, provided data on the per capita use of water. Probable ultimate deliveries of water were estimated by applying the per capita water use to the estimates of ultimate urban population of the area. The water use thus determined was converted to unit use per acre. Estimates of present and probable ultimate unit seasonal values of water delivery to, and consumptive use of water on, urban and suburban water service areas are found in Table 15. The gross delivery was assumed to be equivalent to the consumptive use, because of the limited opportunity for re-use of the water in many of the coastal hydrographic units.

Use of Water in Other Water Service Areas

Unit values of water use on the miscellany of service areas grouped in this category were derived generally from measured or estimated present deliveries of water to the typical development involved. In most cases the estimates were made in terms of per capita use of water, and the actual acreage of the service area was not a significant factor. In such cases the aggregate amount of water deliveries is relatively very small, and negligible recovery of return flow is involved. For purposes of study, therefore, the estimated unit values of delivery of water to these facilities were considered to be also the measures of consumptive use of applied water.

Both the National Forest and Park Services provided estimates of present and probable ultimate unit deliveries of water to all facilities within their jurisdiction. The estimates were generally in terms of per capita use of water and were based on actual measurements and experience. They varied widely from place to place and in type of use, and for this reason are not detailed herein.

Unit values of consumptive use of water by the timber and timber-processing industries, aside from those industrial uses of water included in urban unit values, were derived largely from data obtained from the United States Forest Service. For sawmill operations and plywood manufacture the estimated unit value of consumptive use of water was 1 acre-foot per 185,000 board-feet of lumber produced. Unit values of

TABLE 15

ESTIMATED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY IN URBAN AND SUBURBAN AREAS, NORTH COASTAL AREA

(In feet of depth)

Hydrographic unit		Gross delivery of water*	
Reference number	Name	Present	Probable ultimate
1	Tule Lake	1.0	1.5
2	Shasta Valley	1.7	2.1
3	Scott Valley	1.9	2.2
4	Upper Klamath	1.8	2.0
5	Trinity	1.6	2.2
6	Klamath	2.0	2.2
7	Rogue	0.7	1.2
8	Del Norte	0.7	1.2
9	Redwood Creek	1.0	1.5
10	Mad River	1.0	1.5
11	Upper Eel	1.0	1.5
12	Humboldt	1.1	1.5
13	Mattole	1.0	1.5
14	Mendocino Coast	1.0	1.5
15	Russian River	1.0	1.5
16	Bodega	1.0	1.5

* Assumed equivalent to consumptive use of applied water.

consumptive use of water, as recommended by the Forest Service, were used for anticipated future manufacture of various other wood products, such as paper, pulp, and fiberboard. The use of water in the manufacture of wood pulp, the greatest water-consuming process, was estimated at 64,000 gallons of water per 1,000 board-feet processed.

In the ultimate pattern of land use, marshlands and water surfaces of Upper Klamath Lake and Tule Lake will be important to the Pacific migratory waterfowl flyway. Following consultation with federal agencies, it was assumed that approximately 11,000 acres in Lower Klamath Lake would be maintained ultimately as marshland for waterfowl. Unit values of water use on both Lower Klamath Lake and Tule Lake Refuges were based on evaporation data.

In other water service areas not encompassed by the foregoing specific types of water service, unit values of consumptive use of applied water under probable ultimate conditions of development were assigned on a per capita basis. In such areas, sparse residential, industrial, and recreational development is expected in the future. For areas outside national forests and monuments, it was estimated that the ultimate population density will average about eight persons per square mile, and that per capita consumptive use of water will be about 70 gallons per day. In areas inside national forests and monuments the same per capita use estimates were made, but the population density was assumed to average about four persons per square mile. The period of water use was assumed to be of three months' duration during the summer for areas above 3,000 feet in elevation, while water service for areas below 3,000 feet in elevation was assumed throughout the year.

CONSUMPTIVE USE OF WATER

In general, estimates of the amounts of water consumptively used in the North Coastal Area were derived by applying appropriate unit values of water use to the service areas involved. The estimates represent the seasonal amount of consumptive use of water under mean conditions of water supply and climate. Table 16 presents estimates of present consumptive use of applied water and precipitation in areas having water service, and Table 17 presents corresponding estimates for probable ultimate conditions of development.

FACTORS OF WATER DEMAND

In addition to the amount of water consumptively used in a given service area, certain factors relating to the water requirements, such as necessary rates, times, and places of delivery of water, quality of water, losses of water, etc., have to be given consideration in the design of water development works. In the North Coastal Area the most important of these demand factors are associated with the supply of water for irrigation. Of secondary importance are those related to the supply of water for urban, suburban, recreational, and other uses. Those demand factors most pertinent to design of works to meet water requirements of the North Coastal Area are discussed in the following sections.

Monthly Distribution of Water Demands

Within the season, demand for irrigation water in the North Coastal Area varies from little or none during the winter rainy months to more than 25 per cent of the seasonal total during dry summer months.

TABLE 16

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, NORTH COASTAL AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Unclassified areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
1	Tule Lake	133,000	86,200	2,200	1,000	200	136,000
2	Shasta Valley	75,100	38,800	800	2,400	200	78,500
3	Scott Valley	51,600	37,400	600	400	200	52,800
4	Upper Klamath	6,800	6,800	100	400	0	7,300
5	Trinity	6,500	4,800	100	1,600	0	8,200
6	Klamath	2,300	1,800	0	800	200	3,300
7	Rogue	100	100	0	0	0	100
8	Del Norte	1,400	3,800	0	900	300	2,600
9	Redwood Creek	900	1,400	0	100	0	1,000
10	Mad River	2,000	2,500	0	800	400	3,200
11	Upper Eel	2,300	1,500	0	900	1,000	4,200
12	Humboldt	15,800	16,600	100	4,700	900	21,500
13	Mattole	0	0	0	0	100	100
14	Mendocino Coast	400	600	0	1,100	800	2,300
15	Russian River	18,700	18,200	100	5,600	200	24,600
16	Bodega	400	500	0	200	0	600
	APPROXIMATE TOTALS	317,000	221,000	4,000	20,900	4,500	346,000

TABLE 17

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, NORTH COASTAL AREA

(In acre-feet)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands: Applied water	Irrigated lands: Precipitation	Farm lots: Applied water	Urban and suburban areas: Applied water	Other water service areas: Applied water	Approximate total consumptive use of applied water
1	Tule Lake	284,000	194,000	4,700	2,600	70,200	362,000
2	Shasta Valley	195,000	111,000	2,300	4,400	600	202,000
3	Scott Valley	83,600	67,600	1,200	900	100	85,800
4	Upper Klamath	21,600	21,200	300	1,000	400	23,300
5	Trinity	28,300	23,700	400	7,300	2,000	38,000
6	Klamath	10,900	9,500	100	8,100	1,500	20,600
7	Rogue	700	1,100	0	0	0	700
8	Del Norte	22,200	58,200	100	3,800	700	26,800
9	Redwood Creek	2,300	3,600	0	400	200	2,900
10	Mad River	32,300	44,100	200	3,400	600	36,500
11	Upper Eel	55,900	57,700	400	4,000	2,700	63,000
12	Humboldt	91,100	102,000	400	20,000	1,400	113,000
13	Mattole	5,100	7,600	0	0	300	5,400
14	Mendocino Coast	47,900	93,700	400	4,500	1,700	54,500
15	Russian River	207,000	231,000	1,400	24,000	1,000	233,000
16	Bodega	43,200	43,100	300	800	100	44,400
	APPROXIMATE TOTALS	1,131,000	1,069,000	12,200	85,200	83,500	1,312,000

Available information indicates that considerable variation in water demand also occurs with length of growing season and with distance from the coast. Urban water demands, while substantially higher in summer than in winter months, are far more uniform throughout the season than are those for irrigation. They vary from four to eight per cent of the seasonal total during the months of December through March, to over ten per cent from June through September. Electric power demand is nearly constant throughout the year, with individual monthly demand ranging between seven and nine per cent of the seasonal total. Representative data on monthly distribution of irrigation and urban water demands in the North Coastal Area are presented in Table 18.

Irrigation Water Service Area Efficiency

In study of irrigation water requirements of the North Coastal Area it was found to be desirable to estimate the over-all efficiency of irrigation practice in the various service areas. Irrigation water service area efficiency was measured by the ratio of consumptive use of applied irrigation water to the gross amount of irrigation water delivered to a service area. Present water service area efficiencies were estimated after consideration of geologic conditions of the service areas involved, their topographic position in relation to sources of water supply and to other service areas, consumptive use of water, irrigation efficiency, usable return flow, and urban and suburban sewage outflow. The availability of more than adequate water supplies in the North Coastal Area is not conducive to the attainment of high irrigation efficiencies. Present over-all irrigation efficiency, the ratio of consumptive use of water to total amount of water applied, is estimated at from 40 to 50 per cent, on the average. Efficiencies were derived from areas having measured water supplies with known irrigated acreages and unit water

TABLE 18

DISTRIBUTION OF MONTHLY WATER DEMANDS, NORTH COASTAL AREA

(In per cent of seasonol total)

Locality and purpose	January	February	March	April	May	June	July	August	September	October	November	December	Total
Irrigation demand													
Humboldt County, 1947 through 1951	0	0	0	0.1	0.7	11.1	23.2	29.6	27.1	8.1	0.1	0	100.0
Shasta Valley, 1935-36 through 1952-53	0	0	0.1	10.2	18.3	16.6	21.3	20.1	13.4	0	0	0	100.0
Klamath Project, Tule Lake Division, 1938-39 through 1949-50	0.5	0.5	1.2	8.4	14.6	18.6	25.3	19.5	9.3	1.4	0.4	0.3	100.0
Urban demand													
Eureka, 1952 through 1954	7.1	7.3	7.0	7.1	7.8	8.6	9.3	10.0	10.2	9.7	8.5	7.4	100.0
Santa Rosa, 1945 through 1949	5.4	5.0	5.7	7.8	8.9	11.4	12.8	12.0	10.7	8.2	6.1	6.0	100.0
Ukiah, 1945 through 1949	6.5	6.4	7.6	7.5	8.3	9.2	12.8	12.4	10.8	8.5	5.1	4.9	100.0
Yreka, 1953 estimated	4.3	4.0	4.3	5.9	7.0	8.5	14.4	15.7	13.9	12.2	5.5	4.3	100.0

uses from which consumptive uses could be calculated. Additional factors affecting the estimates of probable ultimate irrigation water service area efficiencies were related to the location and extent of presently undeveloped irrigable lands. For purposes of illustration, the weighted mean values of all irrigation water service area efficiencies within each hydrographic unit of the North Coastal Area are presented in Table 19.

TABLE 19

ESTIMATED WEIGHTED MEAN IRRIGATION WATER SERVICE AREA EFFICIENCY WITHIN HYDROGRAPHIC UNITS, NORTH COASTAL AREA

(In per cent)

Hydrographic unit: Reference number	Hydrographic unit: Name	Present	Probable ultimate
1	Tule Lake	70	75
2	Shasta Valley	85	60
3	Scott Valley	60	50
4	Upper Klamath	30	40
5	Trinity	30	40
6	Klamath	40	40
7	Rogue	50	50
8	Del Norte	50	50
9	Redwood Creek	50	50
10	Mad River	50	55
11	Upper Eel	50	55
12	Humboldt	50	55
13	Mattole	50	50
14	Mendocino Coast	50	50
15	Russian River	65	65
16	Bodega	50	50

WATER REQUIREMENTS

As the term is used in this bulletin, water requirements refer to the amounts of water needed to provide for all beneficial uses of water and for irrecoverable losses incidental to such uses. Those water requirements of the North Coastal Area that are primarily nonconsumptive in nature are discussed in general terms in the ensuing section. Following this, water requirements of the area that are consumptive in nature are evaluated, both for present and for probable ultimate conditions of development.

Requirements of a Nonconsumptive Nature

The principal nonconsumptive water requirements of the North Coastal Area are associated with the preservation and propagation of fish and wildlife, flood control, timber production, and the generation of hydroelectric power. For the most part, such requirements for water are extremely difficult to evaluate other than in conjunction with definite plans for water resource development. Their consideration in this bulletin, therefore, is limited to discussion of their implications as related to planning for future development of water resources.

So far as is known, there is no present requirement in the North Coastal Area for water for purposes of navigation, except for minor uses on the Klamath River in connection with the lumber industry. In view of topographic conditions, it cannot be foreseen that appreciable requirements of such nature will ever develop in the future.

Fish and Wildlife. The abundant water supply and numerous streams tributary to the ocean in the North Coastal Area have contributed to the development of important sport and commercial fishing industries based on the large annual runs of anadromous fishes, principally king salmon, silver salmon, and steelhead rainbow trout. Resident rainbow trout found in the higher reaches of permanent streams, and other trout species occurring throughout the smaller streams and natural lakes of the area, provide additional attractions to sport fishermen.

Steelhead trout are foremost among the game fishes taken in the North Coastal Area and are found in practically all suitable coastal streams. Coast cutthroat trout, an anadromous form also, are taken in many coastal streams, particularly from the Eureka area north. King and silver salmon provide a very important sport fishery in the lower stretches of the larger coastal streams, while silver salmon are also taken in a multitude of the smaller streams. In addition to supporting a valuable sport fishery, the salmon reared in coastal streams are also caught at sea by both sport and commercial fishermen.

Since the young silvers and steelhead trout spend at least one year in fresh water, it is especially important that a suitable stream flow be maintained throughout the year to assure their continued propagation. Some of the most important streams serving as spawning areas for anadromous fishes are the Klamath, Smith, Mad, Eel, Van Duzen, Bear, Mattole, and Russian Rivers, and Redwood Creek. There are also a number of additional streams that provide spawning grounds for salmon and steelhead in the southern part of the North Coastal Area. The largest of these are Ten Mile, Noyo, Big, Navarro, Garcia, and Gualala Rivers. With their present regimen, the low summer flow of these latter streams, when accompanied by heavy surf action, is usually insufficient to maintain the mouth of the stream free from sandbars. These obstructions frequently prevent the passage of anadromous fishes to and from the spawning areas and thus limit their usefulness for fish propagation purposes.

The Klamath Mountains contain a large number of streams and natural lakes which offer excellent trout fishing. Included are the Marble Mountain Wilderness Area and the Trinity Divide Area, where eastern brook and rainbow trout predominate, with brown trout present in certain waters. Trout fishing is available in most of the streams at higher elevations throughout the North Coastal Area, and largemouth black bass and catfish are taken in some part of Modoc County.

Salmon and trout populations are dependent upon the maintenance of adequate stream flows, and in many cases could be increased by the augmentation of natural flows with stored flood waters released during low stream flow periods. The southern coastal streams of the area would be especially benefited by summer and fall releases of stored water, and it appears that supplies could be made available for such purposes without interference with other requirements of the area. Spawning beds on many of the smaller streams tributary to the principal rivers would also be improved if their low flows were increased.

The mountainous regions of the North Coastal Area provide a natural habitat for many forms of wildlife and offer excellent hunting opportunities. Water requirements for big game and upland game, estimated at about 300 acre-feet seasonally, are small compared with other requirements and are expected to remain so in the future. Although small in amount, water supplies for game species should be widely and strategically located in proper relation to basic food and cover sources.

At the request of the Division of Water Resources, a series of estimates of the flow required for the protection and maintenance of fish life in each of the important streams of the North Coastal Area was made by the California Department of Fish and Game. These streams were divided into four classes by the Division according to anticipated degree of development for various purposes that would compete with recreational or commercial fishing requirements. These classes are described, and the summer and winter flow requirements for fish life in streams of Classes I and II, as determined by the Department of Fish and Game, are listed in Appendix F. At the present time, cooperative studies are in progress by the United States Fish and Wildlife Service, the California Department of Fish and Game, the United States Bureau of Reclamation, and the Division of Water Resources to ascertain further data regarding the fisheries resources in the North Coastal Area, with the objective of refining the determinations of requirements.

Hydroelectric Power. The abundant natural runoff of the North Coastal Area and its rugged topography provide essential natural elements for the generation of significant amounts of hydroelectric power. Present hydroelectric development in the area is minor, and represents only a small part of the potential power available. Streams with power developments and the average annual water requirement of the plant with the greatest inflow demand are listed in Table 20.

Estimates of the power obtainable under average conditions of stream flow, and with full utilization of the available head, indicate that an annual total of 13,800,000,000 kilowatt-hours, with an average annual water requirement of about 15,000,000 acre-feet, is theoretically possible. This power output is estimated on the assumption that the water supply is used primarily for power production, with no consideration given to use of water for other purposes. It is probable that the streams of the area ultimately will serve a combination of beneficial uses, and the water utilized for power development under combined operations will be considerably less than the theoretical potential. Estimated theoretical power output, installed power capacity, and required inflow of water at the lowest plant are presented in Table 21 for streams of the North Coastal Area on which power development is feasible.

TABLE 20

PRESENT HYDROELECTRIC POWER DEVELOPMENT, NORTH COASTAL AREA

Stream	Number of power plants	Installed power capacity, in kilowatts	Present annual water requirement, in acre-feet
Klamath River	3	49,200	1,500,000
Trinity River	1	2,700	11,000
Eel River	2	9,450	215,000
TOTALS	6	61,350	--------

TABLE 21

EXISTING AND ESTIMATED POTENTIAL HYDROELECTRIC POWER DEVELOPMENT, NORTH COASTAL AREA

Stream	Average annual power output, in 1,000,000 kilowatt-hours	Installed power capacity, in kilowatts	Required average annual inflow of water at lowest plant, in 1,000 acre-feet
Smith River	760	160,000	1,670
Trinity River	2,980	620,000	2,420
Klamath River in California (less Trinity River)	6,880	1,430,000	4,500
Redwood Creek	85	15,000	400
Mad River	550	115,000	555
Van Duzen River	270	55,000	550
Eel River	1,980	410,000	3,110
Mattole River	130	25,000	575
Navarro River	30	5,000	225
Gualala River	35	5,000	320
Russian River	100	20,000	820
APPROXIMATE TOTALS	13,800	2,860,000	15,140

Flood Control. Flood control, whether achieved by channelization or by storage, has as its objective the movement of flood flows to the ocean as rapidly as possible with the maximum protection against flooding of developed areas. Water dedicated to regulation for flood control purposes is largely unavailable for other purposes and usually results in a net loss to the available water supply. At present the only storage development for flood control in the North Coastal Area is Clear Lake Reservoir in Modoc County, which regulates the runoff of Lost River. The reservoir was originally designed for flood control, with regulation achieved by storage and evaporation of floodwaters. Evaporation from the reservoir has amounted to about two-thirds of the total average water supply to the reservoir, or about 60,000 acre-feet annually. Under present conditions of development all available water in the reservoir in excess of evaporation and other losses is utilized by irrigable lands in the Klamath Project.

The Coyote Project on the East Fork of the Russian River near Ukiah has been authorized for construction by the United States Army Corps of Engineers as a flood control and water conservation project. This project would impound waters heading in the Russian River drainage basin, as well as diversions from the Eel River through the Potter Valley Power Plant. In addition to winter flood control, the Coyote Project would provide agricultural and urban water supplies to valley floor lands. Summer flow in the lower reaches of the Russian River, greatly enhancing the recreational potential of the area, would also be provided by the project. Other existing flood control projects in the North Coastal Area are generally limited to minor levee and bank protection works.

Timber and Timber By-products. Available data from the United States Forest Service and mill production records indicate that in the future more of the cull timber and logging and mill residues probably will be used for manufacture of such products as pulp and fiberboard. It is estimated that these residues could provide about 155,000,000 cubic feet of chips for pulp processing annually. The water requirement for the sulphate process of making pulp, which is best adapted to the use of coniferous woods such as pine, fir, and spruce that prevail in the area, averages about 56,000 gallons per 200 cubic feet of chips. It is estimated that 75 per cent of these residues would be processed within the North Coastal Area, requiring water in the amount of about 99,000 acre-feet annually, while the remaining 25 per cent would be processed by mills situated in the San Francisco Bay Area, with an annual water requirement of 33,000 acre-feet. Water for processing is not used consumptively, but plant effluents are so highly acidic as to require treatment in order to prevent obnoxious pollution, destruction of fish life, and impairment of recreational values.

In evaluating the probable future requirement for water by the timber industry in the North Coastal Area, it was assumed the previously computed 99,000 acre-feet of water per season for pulp processing would be obtained from local sources. This requirement very likely would occur in the lower reaches of the stream systems, and re-use of the water would probably not occur. It was also assumed an additional 3,000 acre-feet of water per season would be required for fiberboard production, while the requirement for maintaining log ponds and other miscellaneous uses in sawmill operation would be about 6,000 acre-feet seasonally. The three estimates result in a total of 108,000 acre-feet of water per season required for the timber industry in the North Coastal Area under conditions of ultimate development.

TABLE 22

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER, NORTH COASTAL AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots		Urban and suburban areas		Other water service areas		Approximate totals	
Reference number	Name	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate
1	Tule Lake	193,000	388,000	2,200	4,700	1,000	2,500	200	70,200	196,000	465,000
2	Shasta Valley	86,600	320,000	800	2,300	2,400	4,500	200	600	90,000	327,000
3	Scott Valley	83,900	168,000	600	1,200	300	800	200	100	85,000	170,000
4	Upper Klamath	22,300	55,200	100	300	400	900	0	400	22,800	56,800
5	Trinity	21,500	70,900	100	400	1,600	7,300	0	2,000	23,200	80,600
6	Klamath	5,600	27,900	0	100	800	8,100	200	1,500	6,600	37,600
7	Rogue	200	1,400	0	0	0	0	0	0	200	1,400
8	Del Norte	2,800	44,400	0	200	900	3,900	300	700	4,000	49,200
9	Redwood Creek	1,800	4,600	0	0	100	500	0	200	1,900	5,300
10	Mad River	4,000	58,700	0	400	800	3,500	400	600	5,200	63,200
11	Upper Eel	4,600	102,000	0	800	1,000	4,100	1,000	2,700	6,600	110,000
12	Humboldt	31,600	166,000	200	800	4,700	20,000	900	1,400	37,400	188,000
13	Mattole	0	10,200	0	0	0	0	100	300	100	10,500
14	Mendocino Coast	800	95,800	0	800	1,100	4,500	800	1,700	2,700	103,000
15	Russian River	28,800	318,000	200	2,800	5,700	24,000	200	1,000	34,900	346,000
16	Bodega	800	86,400	0	600	200	700	0	100	1,000	87,800
	APPROXIMATE TOTALS	488,000	1,917,000	4,200	15,400	21,000	85,300	4,500	83,500	518,000	2,101,000

Mining. Mining operations in the North Coastal Area are not expected to involve significant requirements for water. Future production of many minerals will probably utilize processes somewhat different than those requiring excessive water utilization which were employed in former years. The milling of gold ore, the washing of sand and gravel, and refining of copper, silver ores, manganese, and chromite require only minor amounts of water. The quarrying of building stone, and pumice and diatomaceous earth production use only negligible amounts of water.

Requirements of a Consumptive Nature

Estimates of present and probable ultimate water requirements of a consumptive nature within hydrographic units of the North Coastal Area are presented in Table 22. These mean seasonal values represent the water other than precipitation needed to provide for beneficial consumptive use of water on irrigated land, urban and suburban areas, farm lots, and other water service areas, and for irrecoverable losses of water incidental to such use. The estimates were derived from consideration of the heretofore presented estimates of consumptive use of applied water, and of water service area efficiencies of hydrographic units.

Supplemental Requirements

The probable ultimate supplemental water requirement for each hydrographic unit was measured as the difference between the yield of presently developed supplies and the estimated ultimate requirement for water. In the North Coastal Area much of the water utilized for irrigation, for municipal purposes, or for other miscellaneous uses is diverted from the flowing streams or pumped from the ground as needed. Positive action for development of water supplies has not, in general, been required in the North Coastal Area because of the great excess of supply over requirements. Estimates of yield of presently developed water supplies in this area were, therefore, assumed equivalent to present requirements. This assumption could only be made in an area such as the North Coastal Area, where water is far more abundant than present utilization, and no known ground water overdrafts exist.

Estimates of probable ultimate mean seasonal supplemental water requirements of hydrographic units of the North Coastal Area are presented in Table 23.

TABLE 23

ESTIMATED PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS, NORTH COASTAL AREA

Hydrographic unit		Acre-feet
Reference number	Name	
1	Tule Lake	269,000
2	Shasta Valley	237,000
3	Scott Valley	85,000
4	Upper Klamath	34,000
5	Trinity	57,400
6	Klamath	31,000
7	Rogue	1,200
8	Del Norte	45,200
9	Redwood Creek	3,400
10	Mad River	58,000
11	Upper Eel	103,000
12	Humboldt	151,000
13	Mattole	10,400
14	Mendocino Coast	100,000
15	Russian River	311,000
16	Bodega	86,800
	APPROXIMATE TOTAL	1,583,000

CHAPTER IV

SAN FRANCISCO BAY AREA

The San Francisco Bay Area lies between latitudes 37° and 38.5° N. and consists of the drainage areas of streams discharging into the Pacific Ocean inclusive of Lagunitas Creek on the north and Pescadero Creek on the south, as well as all stream basins draining into San Francisco, San Pablo, and Suisun Bays below points on the Sacramento River near Collinsville and the San Joaquin River near Pittsburg. The area is designated Area 2 on Plate 8, and includes major portions of Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano, and Sonoma Counties, all of San Francisco County, and a small portion of Santa Cruz County. The principal urban centers are the large metropolitan areas in and adjacent to the City of San Francisco, and the Cities of Berkeley, Oakland, Alameda, Richmond, Vallejo, Redwood City, Palo Alto, and San Jose.

For the purpose of hydrologic analysis, the San Francisco Bay Area was subdivided into 10 hydrographic units, as delineated on Plate 8. The boundaries of the units were established with consideration to geography, size, climate, and grouping of political subdivisions. Table 24 lists the 10 hydrographic units and their areas, and Table 25 presents the areas of the portion of each county included within the San Francisco Bay Area. Land areas shown are necessarily approximate, principally because of the continuing program of tideland reclamation. The areas of San Francisco Bay and that portion of Tomales Bay in the Marin-Sonoma Hydrographic Unit were not included in the tabulated areas.

The climate of the San Francisco Bay Area has long been noted for moderate temperatures, relatively light precipitation, and summer fog along the coast. The mean seasonal temperature in San Francisco is 56.5° F., while that at San Jose is about 60° F. This temperature differential is principally caused by summer fog, resulting in about 10 per cent less sunshine hours at San Francisco than at San Jose.

TABLE 24

AREAS OF HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

Hydrographic unit: Reference number	Hydrographic unit: Name	Acres
1	Marin-Sonoma	436,000
2	Napa Valley	266,000
3	Solano	220,000
4	Contra Costa	237,000
5	Livermore Valley	406,000
6	Alameda-Bayside	219,000
7	Santa Clara Valley	455,000
8	San Mateo-Bayside	115,000
9	San Mateo-Coastal	155,000
10	San Francisco	29,200
	APPROXIMATE TOTAL	2,538,000

TABLE 25

AREAS OF COUNTIES WITHIN BOUNDARIES OF SAN FRANCISCO BAY AREA

County	Acres
Alameda	431,000
Contra Costa	289,000
Marin	256,000
Napa	275,000
San Francisco	29,200
San Mateo	267,000
Santa Clara	597,000
Santa Cruz	3,400
Solano	210,000
Sonoma	180,000
APPROXIMATE TOTAL	2,538,000

Precipitation varies widely throughout the area, generally increasing with elevation, but decreasing with distance from the coast. Mean seasonal depth of precipitation for the entire area is approximately 23.4 inches, while that on the valley and mesa land is about 20 inches. Variations from mean seasonal precipitation of from 50 per cent to 200 per cent in individual seasons are not uncommon. Approximately 90 per cent of the precipitation occurs during the six-month period of November through April.

The mean seasonal natural runoff of streams of the San Francisco Bay Area is estimated to be about 1,245,000 acre-feet, or 1.8 per cent of that for the entire State. About 30 per cent of the runoff occurs in the Napa River, and Alameda and Coyote Creeks. The remainder is divided among the many small streams of the area. The estimated mean seasonal runoff of the Napa River, the largest stream, is about 186,000 acre-feet. Stream flow directly reflects the amount and intensity of precipitation. Under mean conditions, about 90 per cent of the natural runoff occurs during the period from November through April.

Eleven valley fill areas, which may or may not contain usable ground water, have been identified in the San Francisco Bay Area, and are shown on Plate 4. The principal valley fill areas include the Petaluma, Napa-Sonoma, Suisun-Fairfield, Santa Clara, and Livermore Valleys. Other smaller areas include the Pittsburg Plain, and Clayton, Ygnacio, San Ramon,

San Francisco

Courtesy State Division of Highways

Santa Clara Valley Orchard

Courtesy San Jose Chamber of Commerce

Castro, and Sunol Valleys. In addition to the areas shown on Plate 4, several smaller basins of minor local importance are known to exist. Water from subsurface basins is presently used extensively for agricultural and urban purposes. Ground water supplies in some areas have only recently been developed, while in other areas excessive withdrawals over long periods of time have caused overdrafts, evidenced by lowering of water tables and, in some cases, by degradation of water quality. Ground water will be of considerable importance in meeting future requirements for water, and detailed studies of ground water conditions in the most important basins are currently being made by the Division of Water Resources and the United States Geological Survey.

From the earliest days, agricultural enterprises of the San Francisco Bay Area have fallen into two general groups, one supplying fresh fruit, vegetables, flowers, poultry, and dairy products to the metropolitan area, and the other producing fruit, grain, wine, and cattle for use throughout the State and Nation. Historically, irrigation has been carried on extensively in the first group, while seldom practiced in the second. However, at present a large acreage of fruit, formerly dry-farmed, receives irrigation. The following quotations, taken from the first agricultural census in 1890, pointed the way of things to come:

"Alameda County . . . noted for the large quantity of fruit produced . . . ."

"Contra Costa County . . . fruit culture is of great importance . . . . Owing to its proximity to the City of San Francisco considerable areas on the lowlands are devoted to market gardening . . . ."

"Marin County . . . . The principal industry is dairy farming, the City furnishing a constant market . . . ."

"Napa County . . . . The chief source of wealth is in the vineyards, whose products are known throughout the country . . . also every variety of the so-called deciduous fruits is produced."

"San Francisco County . . . . Agriculture can hardly be said to be carried on within the county, but enumerators have found a number of areas under cultivation. These are principally devoted to truck farming . . . raising crop after crop in as rapid succession as conditions will permit."

"San Mateo County . . . . Agriculture is carried on to a small extent . . . ."

"Santa Clara County . . . . Throughout the broad Santa Clara Valley and along the adjoining foothills the cultivation of fruit is carried on extensively . . . . Among the fruits prunes are probably the most important, and next to these come peaches, apricots, and then the vineyards . . . . Much of the fruit is shipped to market in the undried or what is known as green condition . . . ."

"Solano County . . . large quantities of fruit are produced . . . ."

"Sonoma County . . . noted for its vineyards and perhaps to a less extent for its fine orchards . . . ."

Today, land of unquestionable value for agricultural pursuits is being used for urban types of development. San Francisco's strategic location on the west coast, as well as its outstanding natural harbor, the principal inlet to and outlet from the great Central Valley of California, will undoubtedly continue to cause expansion of the area as a major industrial center. For these reasons, water utilization and requirements for the San Francisco Bay Area were studied with a view to ultimate urbanization, rather than to increased use of land for irrigated agricultural purposes. It is anticipated, however, that agriculture will continue to play a role, particularly in the economy of the counties north of the bay.

The relatively high degree of urbanization in the San Francisco Bay Area is shown by the fact that, in both 1900 and 1950, about 75 per cent of the total population was found in incorporated cities of over 10,000. The recent increase in urbanization, particularly since 1940, is not entirely reflected in this value, since quite a large portion consists of the growth of unincorporated suburban communities.

Growth of population in the San Francisco Bay Area in recent years has been approximately proportional to that in the State as a whole. The total population of the area in 1940 has been estimated at 1,652,-000, while the 1950 population was approximately 2,555,000, representing an increase of 55 per cent during the decade. As of 1950, 86 per cent of the total population was living within the San Francisco-Oakland and San Jose urbanized areas, as outlined by the United States Bureau of the Census. The 1940 and 1950 populations of the 11 largest cities in the area are presented in Table 26, together with the populations of such parts of the unincorporated urbanized areas as are nearest each city. For the purpose of this comparative illustration, it was necessary to estimate the 1940 populations in unincorporated portions of the urbanized areas.

The economic basis of the San Francisco Bay Area has long been closely associated with shipping and foreign commerce, but, until recently, there has not been an extensive heavy manufacturing industrial development. Lack of developed supplies of raw materials, except in the case of agricultural commodities, has in the past largely restricted manufacturing activity to the assembly of finished goods from parts fabricated in the east. However, a greatly increased population, together with the stimulation provided by war production requirements, has recently given rise to a very significant growth in basic industries.

The industries presently supporting the expanding population are associated with the excellent sea, rail-

Urban Growth in
San Francisco Bay Area

Courtesy Davis Photo Service

TABLE 26

POPULATION OF PRINCIPAL URBAN CENTERS, SAN FRANCISCO BAY AREA

City	1940			1950		
	Within city limits	In suburbs	Total	Within city limits	In suburbs	Total
San Francisco	635,000	68,300	703,000	775,000	124,000	899,000
Oakland	302,000	12,400	314,000	385,000	13,000	398,000
San Jose	68,500	36,500	105,000	95,300	66,800	162,000
Richmond	23,600	10,400	34,000	99,500	44,900	144,000
Berkeley	85,500	14,800	100,000	114,000	24,000	138,000
San Leandro	14,600	24,600	39,200	27,500	73,200	101,000
Vallejo	20,100	17,300	37,400	26,000	56,900	82,900
San Mateo	19,400	24,100	43,500	41,800	39,100	80,900
Palo Alto	16,800	17,700	34,500	25,500	47,900	73,400
Alameda	36,300	0	36,300	64,400	0	64,400
Redwood City	12,500	10,500	23,000	25,500	29,300	54,800

way, and highway transportation networks terminating in the San Francisco Bay Area. Oil refineries, chemical enterprises, and paper mills are found along Suisun and San Pablo Bays, and salt reduction works along the shores of South San Francisco Bay, while fabricating, food product, and textile plants are distributed throughout the area. Military installations at Hamilton Field, Mare Island, Benicia Arsenal, and Travis Air Force Base provide major employment opportunities in the area north of the bay. Other installations providing defense employment opportunities are the Naval Training Center at Treasure Island, the Alameda Naval Air Station, Moffett Field, Hunter's Point Naval Shipyard, and the Oakland Naval Supply Depot. In addition to those named, many other defense installations are located in the San Francisco Bay Area.

The increasing population of the San Francisco Bay Area is causing an expansion of the urban area and an intensified usage of previously developed urban lands. Alluvial plains between the hills and the marshlands were among the first lands to be occupied for urban purposes. Urban developments have since expanded into the adjacent foothills and marshlands, and into nearby developed agricultural lands on the alluvial plains. The marshlands, requiring extensive reclamation prior to utilization for urban activities, were among the last to be occupied. Most reclamation of marshlands has been undertaken for commercial, industrial, or agricultural purposes, although quite recently residential development has occurred in small areas of reclaimed marshland in Marin and San Mateo Counties.

In the area south of the San Francisco-Oakland Bay Bridge, practically all marshlands have either been reclaimed or are being held for future use as salt evaporation ponds. Adjacent to the City of San Francisco and to the East Bay metropolitan area, reclamation has already extended across the marsh- and tidelands into areas of submerged land. Nearly all marsh areas in Marin County have been reclaimed in the past, or are presently being reclaimed. Extensive areas of unreclaimed marshlands still exist along the north shore of San Pablo Bay and on both sides of Suisun Bay.

Prior to the gold rush of 1849, the ranches and small settlements in the San Francisco Bay Area obtained their necessary water supplies from nearby springs and streams. During gold rush days in San Francisco, water in barrels was brought by barge across the bay from Sausalito, and was then distributed from wagons. The first imported water supply for San Francisco was received through a system of flumes and tunnels constructed between the city and Lobos Creek by the San Francisco Water Works in 1857. A competing company, the Spring Valley Water Company, began developing supplies on the peninsula south of the city, and in 1865 absorbed the San Francisco Water Works. By 1890, four reservoirs had been constructed on the peninsula, and the possibility of further development of local water supplies of the peninsula was essentially exhausted. Alameda Creek, on the easterly shore, was then tapped, first at Niles Canyon, followed by the Pleasanton well field, and finally by filter galleries near Sunol. Storage of local runoff was developed in Calaveras Reservoir by 1925.

Agitation for a municipally owned water system in San Francisco grew out of dissatisfaction with service rendered by the private company, and led to the inclusion of authorization for such a system in the charter of 1900. The first action taken under this authorization was the investigation of available sources of supply located outside the San Francisco Bay Area. Many possible developments were considered, and the Tuolumne River was chosen as being the most advantageous under conditions then existing. The main storage sites selected, Hetch Hetchy Reservoir and Lake Eleanor, are located within the limits of Yosemite National Park. A lengthy and arduous struggle, with recreation and naturalist interests opposing the development, followed. The Raker Act, passed by Congress in 1913, concluded the controversy generally in favor of the city. Hydroelectric power installations were included in the development plan, in addition to the water storage and conveyance features of the project. The primary stage of the project was constructed and placed in use by 1934. The most recent expansion of the Hetch Hetchy system is the Cherry Valley Reservoir project, currently under construction. In 1930, the City and County of San Francisco purchased the properties of the Spring Valley Water Company. The present safe yield of the Hetch Hetchy system is limited by the capacity of the two aqueduct lines crossing the San Joaquin Valley to 140,000,000 gallons per day, or about 157,000 acre-feet per year. The total right to waters of the Tuolumne River claimed by the City and County of San Francisco is 400,000,000 gallons per day, or 448,000 acre-feet per year.

The East Bay Municipal Utility District is the principal water service agency in the East Bay area, and serves an area extending from San Lorenzo and Castro Valley in Alameda County on the south, to the town of Rodeo on the north, and easterly to Walnut Creek and Pleasant Hills in the center of Contra Costa County. Early development of local supplies in the service area was undertaken by private concerns, the most prominent of which were the Contra Costa Water Company, the Peoples Water Company, and the East Bay Water Company. As the need for imported supplies became evident, voters of the region established the East Bay Municipal Utility District in 1923. The district decided that development of the Mokelumne River represented the best source of water supply for the area. In 1929 the district constructed Pardee Reservoir in the foothills of the Sierra Nevada near Lancha Plana, and an aqueduct crossing the Central Valley to the service area. Hydroelectric power produced below Pardee Dam contributes to the financing of the project. In 1928 the district assumed control of the properties of the East Bay Water Company. The district is able at present to deliver 145,000,000 gallons per day, or 162,500 acre-feet per year, from the Mokelumne River system. The district presently claims rights in Mokelumne River waters to a total of 200,000,000 gallons per day, or 224,000 acre-feet of water per year. An application by the district for the right to expand the system further so as to deliver an additional 125,000,000 gallons per day, or 140,000 acre-feet per year, is presently under consideration by the Division of Water Resources.

The Marin Municipal Water District, organized in 1912, supplies water to the most heavily populated southerly portion of Marin County. Lagunitas Creek, draining the slopes of Mount Tamalpais, is the source of water supply. This district was also preceded by several private water utilities, of which the Marin County Water Company was the most important.

The Contra Costa County Water District was organized in 1936 to distribute water from the Contra Costa Canal, built by the United States Bureau of Reclamation as a feature of the Central Valley Project. The present yearly rate of importation to that portion of the district within the San Francisco Bay Area is about 40,000 acre-feet. The canal is designed to eventually deliver water at the rate of 270 second-feet, equivalent to about 195,000 acre-feet per year, to the San Francisco Bay Area.

The City of Vallejo has recently commenced importation of water from Cache Slough in the Central Valley Area. It is estimated that this import will amount to about 21,000,000 gallons per day, or about 23,000 acre-feet of water per year.

In addition to the foregoing, several smaller municipal systems serve communities in the area.

The San Jose Water Works, serving the City of San Jose and surrounding territory, is a privately owned public utility. The California Water Service Company owns and operates water supply systems in 18 communities in the San Francisco Bay Area. At the present time a total of 145 agencies were supplying water in the area. Water service agencies in this area are listed by counties in Appendix B. Plate 12 shows the location of the principal water supply agencies and works of the San Francisco Bay Area, and Plate 14 illustrates trends of historical importations of water to the area.

The history of the major water service agencies operating in the San Francisco Bay Area indicates a trend toward the consolidation of small agencies into large public districts. It appears that, because of the capital investment required, large-scale water supply developments can best be accomplished through the efforts of such public agencies.

At the present time approximately 17 per cent of the land acreage in the San Francisco Bay Area is included in water service areas. About 60 per cent of these lands are used for urban and military purposes and the remaining lands are used for irrigated agriculture.

The principal water problems of the San Francisco Bay Area result from rapidly increasing population, together with intensification of agricultural activities and expanding practice of irrigation. In general, the requirement for water to meet the urban phase of this problem has been met by increased importations and by development of local supplies through construction of new surface storage works. Since World War II, nearly every major water service agency has increased its storage or conveyance facilities in order to satisfy demands for service. Despite these increases in facilities, the available water supply has barely kept pace with the demand.

Growing agricultural water requirements have been met largely by increased ground water pumpage, which in several localities has introduced the previously mentioned problem of ground water overdraft. The effects of ovedraft have been experienced in lowering of water tables and degradation in quality of ground water.

The possibility of damage from floods has always existed in certain portions of the San Francisco Bay Area, but the expansion of residential development along the bay shores and into areas of reclaimed marshland has aggravated the problem of flood damage and control. Much of the residential development which took place in the relatively dry seasons of 1947, 1948, and 1949, without sufficient consideration being given to drainage, was subjected to flooding in the wetter seasons of 1950, 1951, and 1952.

Future development in the San Francisco Bay Area will depend in large measure upon fulfillment of the increased water requirements for all purposes. There follows a presentation of available data and estimates pertinent to the nature and extent of water requirements in the San Francisco Bay Area, both at the present time and under conditions of probable ultimate development.

PRESENT WATER SERVICE AREAS

As a necessary step in estimating present water requirements in the San Francisco Bay Area, determinations were made of the location, nature, and extent of presently irrigated and urban and suburban water service areas. Remaining lands were not classified in detail with regard to their relatively minor miscellaneous types of water service, although such water service was given consideration in estimating the present water requirement.

Irrigated Lands

It was determined that an average of about 163,000 acres in the San Francisco Bay Area are irrigated each year under present conditions of development. This constitutes about 2.4 per cent of the total irrigated area in California. Orchards comprise approximately 55 per cent, and truck crops about 25 per cent of the total irrigated acreage.

The field surveys upon which determinations of irrigated acreage in the San Francisco Bay Area were based were accomplished in 1949 by the State Division of Water Resources, largely in connection with special investigations covering portions of the area. On the basis of available survey data, the irrigated lands were classified into various crop groups with a view to segregating those of similar water use. Detailed segregation of individual truck and nursery crops was found to be impracticable. A list of the various crop groups into which irrigated lands of the San Francisco Bay Area were classified follows:

Alfalfa ....Hay, seed, and pasture
Pasture ....Grasses and legumes, other than alfalfa, used for livestock forage
Beans ....String, lima, wax, and other
Flowers ....Flowers, seed, and nursery crops
Grain ....Miscellaneous grains
Orchard ....Almonds and prunes
Orchard ....Walnut
Orchard ....Other deciduous, apricots, apples, olives, peaches, and pears
Sugar beets
Truck crops ....Intensively cultivated fresh vegetables, including lettuce, celery, brussels sprouts, broccoli, artichokes, tomatoes, and corn
Vineyard ....All varieties of grapes

Dry-farmed land is used for grain, orchards, pasture and hay, and vineyards, but is not considered part of the present water service area. The total acreage of dry-farmed land is shown in subsequent tabulations, to afford a comparison with the present extent of irrigation. Farm lots, consisting of farm buildings and areas immediately surrounding them, are included as a part of other water service areas in the San Francisco Bay Area.

Summaries of presently irrigated acreages within the San Francisco Bay Area by the various crop groups are presented in Tables 27 and 28. Table 27 lists the acreages by hydrographic units, and Table 28 by counties.

TABLE 27

AREAS OF PRESENTLY IRRIGATED AND DRY-FARMED LANDS WITHIN HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

(In acres)

Hydrographic unit		Net irrigated												
Reference number	Name	Alfalfa	Pasture	Beans	Flowers	Grain	Orchard, almond, prune	Orchard, walnut	Orchard, other deciduous	Sugar beets	Truck crops	Vineyard	Approximate total	Dry-farmed
1	Marin-Sonoma	100	1,200	0	0	100	100	100	200	0	400	-------	2,200	29,600
2	Napa Valley	0	900	0	0	300	200	100	0	0	1,100	0	2,600	50,000
3	Solano	0	100	0	0	100	1,800	100	5,500	0	200	500	8,300	38,200
4	Contra Costa	0	-------	0	-------	200	300	2,900	1,100	0	1,200	300	6,000	25,500
5	Livermore Valley	700	800	200	400	600	-------	600	300	900	2,000	500	7,000	31,500
6	Alameda-Bayside	800	2,400	1,300	300	400	100	500	3,900	2,900	11,200	-------	23,800	29,100
7	Santa Clara Valley	2,500	2,900	1,100	0	100	43,500	6,000	27,400	3,000	16,800	2,200	105,000	31,000
8	San Mateo-Bayside	-------	-------	0	1,100	-------	0	-------	100	0	1,200	0	2,400	9,200
9	San Mateo-Coastal	-------	200	500	200	-------	0	0	-------	0	4,300	0	5,200	28,300
10	San Francisco	0	0	0	0	0	0	0	0	0	0	0	0	0
	APPROXIMATE TOTALS	4,100	8,500	3,100	2,000	1,800	46,000	10,300	38,500	6,800	38,400	3,500	163,000	272,000

Courtesy State Division of Highways

Urban Development in San Francisco

TABLE 28

AREAS OF PRESENTLY IRRIGATED AND DRY-FARMED LANDS WITHIN COUNTIES, SAN FRANCISCO BAY AREA

(In acres)

County	Net irrigated												Dry-farmed
	Alfalfa	Pasture	Beans	Flowers	Grain	Orchard, almond, prune	Orchard, walnut	Orchard, other deciduous	Sugar beets	Truck crops	Vineyard	Approximate total	
Alameda	1,500	3,200	1,500	700	1,000	100	800	4,000	3,800	13,200	400	30,200	56,700
Contra Costa	0	-----	0	-----	200	300	3,200	1,300	0	1,300	400	6,700	29,500
Marin	100	400	0	0	-----	0	100	-----	0	-----	-----	600	3,000
Napa	0	900	0	0	300	200	100	0	0	1,100	0	2,600	48,000
San Francisco	0	0	0	0	0	0	0	0	0	0	0	0	0
San Mateo	-----	200	500	1,300	-----	0	-----	100	0	5,500	0	7,600	37,500
Santa Clara	2,500	2,900	1,100	0	100	43,500	6,000	27,400	3,000	16,800	2,200	105,000	31,000
Santa Cruz	0	0	0	0	0	0	0	0	0	0	0	0	0
Solano	0	100	0	0	100	1,800	100	5,500	0	200	500	8,300	40,200
Sonoma	0	800	0	0	100	100	0	200	0	300	0	1,500	25,600
APPROXIMATE TOTALS	4,100	8,500	3,100	2,000	1,800	46,000	10,300	38,500	6,800	38,400	3,500	163,000	272,000

Urban and Suburban Water Service Areas

It was determined that under present conditions of development in the San Francisco Bay Area approximately 225,000 acres are devoted to urban and suburban types of land use. For the most part the business, commercial, and industrial establishments and surrounding homes included in this areal classification receive a municipal type of water supply.

Detailed land use surveys were made in this area, with particular attention being given to the highly urbanized metropolitan area. The results of the survey are presented on Plate 10, "Present Land Use in San Francisco Bay Area." Urban and suburban areas were further divided into the broad classes of residential, industrial, commercial, institutional, park, and streets, including vacant lands. These classes of land use were further subdivided as follows:

Residential types of land use were separated into single and multiple occupancy. Although dwellings designed to house not more than two families were grouped in the "single" classification, single-family residences were predominant in this type of use. Multiple residential uses included all structures housing three or more family units. Both classes included minor areas used for schools and parks such as are normally found in residential developments.

Industrial types of land use were further divided into three subclasses in accordance with their estimated water requirements. General industrial uses, designated as "industrial" on Plate 10, include manufacturing, storage, transportation, and wholesale distribution facilities. Industries with minor water demands, shown on Plate 10 as "low water-using industrial," include oil tank farms, powder and explosive storage, and salt evaporation ponds. Airfields and appurtenant facilities are the third class of industrial use considered.

TABLE 29

PRESENT URBAN AND SUBURBAN AREAS WITHIN HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

(In acres)

Hydrographic unit		Area requiring water service									Area not requiring water service		Approximate gross area
		Residential		Industrial									
Reference number	Name	Single	Multiple	General	Low water-using	Airfields	Commercial	Institutions	Irrigated parks	Subtotal	Streets and vacant	Nonirrigated parks	
1	Marin-Sonoma	4,600	-----	400	0	100	500	500	300	6,400	8,800	-----	15,200
2	Napa Valley	3,100	600	200	0	800	300	500	300	5,800	3,300	100	9,200
3	Solano	500	-----	-----	0	-----	100	-----	200	800	700	0	1,500
4	Contra Costa	7,400	800	3,300	2,400	100	500	400	600	15,500	14,200	-----	29,700
5	Livermore Valley	600	-----	-----	0	200	100	100	-----	1,000	2,500	100	3,600
6	Alameda-Bayside	17,500	1,100	3,400	15,000	1,000	2,000	1,300	1,500	42,800	27,800	600	71,200
7	Santa Clara Valley	10,300	300	1,600	7,900	200	800	600	600	22,300	10,500	-----	32,800
8	San Mateo-Bayside	7,300	200	1,000	5,600	1,100	300	300	2,100	17,900	15,700	100	33,700
9	San Mateo-Coastal	800	-----	-----	0	100	100	-----	600	1,600	1,500	0	3,100
10	San Francisco	7,200	1,600	1,600	0	0	1,200	800	2,900	15,300	10,400	0	25,700
	APPROXIMATE TOTALS	59,300	4,600	11,500	30,900	3,600	5,900	4,500	9,100	129,000	95,400	900	225,000

TABLE 30

PRESENT URBAN AND SUBURBAN AREAS WITHIN COUNTIES, SAN FRANCISCO BAY AREA

(In acres)

County	Area requiring water service									Area not requiring water service		Approximate gross area
	Residential		Industrial			Commercial	Institutions	Irrigated parks	Subtotal	Streets and vacant	Nonirrigated parks	
	Single	Multiple	General	Low water-using	Airfields							
Alameda	18,100	1,100	3,400	15,000	1,200	2,100	1,400	1,500	43,800	30,300	700	74,800
Contra Costa	7,400	800	3,300	2,400	100	500	400	600	15,500	14,200	----	29,700
Marin	3,300	0	200	0	100	300	400	100	4,400	4,500	----	8,900
Napa	1,300	----	100	0	700	200	400	200	2,900	1,400	100	4,400
San Francisco	7,200	1,600	1,600	0	0	1,200	800	2,900	15,300	10,400	0	25,700
San Mateo	8,100	200	1,000	5,600	1,200	400	300	2,700	19,500	17,200	100	36,800
Santa Clara	10,300	300	1,600	7,900	200	800	600	600	22,300	10,500	----	32,800
Santa Cruz	0	0	0	0	0	0	0	0	0	0	0	0
Solano	2,300	600	100	0	100	200	100	300	3,700	2,600	0	6,300
Sonoma	1,300	----	200	0	0	200	100	200	2,000	4,300	0	6,300
APPROXIMATE TOTALS	59,300	4,600	11,500	30,900	3,600	5,900	4,500	9,100	129,000	95,400	900	225,000

Commercial land uses include retail stores, office buildings, garages, hotels, and miscellaneous types of similar establishments. The institutional classification includes land utilized for universities, hospitals, homes for the aged, and miscellaneous.

Areas classified as parks were further divided into subgroups designated as irrigated and nonirrigated. This class also includes cemeteries. Municipal parks only were included with the urban and suburban types of land use. Street and sidewalk areas within large parks were included in the park areas. The "street and vacant" land use classification includes streets, sidewalks, and vacant lots located within the area classified as urban.

The acreages of urban and suburban water service areas within each hydrographic unit of the San Francisco Bay Area are listed in Table 29 and within each county in Table 30.

Unclassified Areas

Remaining lands in the San Francisco Bay Area, other than those that are irrigated or urban and suburban in character, were not classified in detail with regard to present water service. Of a total of about 2,150,000 acres of such remaining lands, about 50,000 acres actually receive water service at the present time. These service areas consist of farm lots and military reservations, and were not segregated among hydrographic units or counties.

Farm lots consist of farm buildings and areas immediately surrounding them receiving water service. The lands devoted to this use amounted to about 13,000 acres in 1949. The gross area of lands included within military reservations was about 37,000 acres. No breakdown in accordance with type of military use, i.e., housing, industrial, etc., was made in this classification.

State parks and similar areas were not included in the unclassified areas receiving water service in the San Francisco Bay Area. In most of these recreational areas the use of water is relatively minor, and is confined principally to administrative areas and public camp grounds.

Summary

Present water service areas within hydrographic units of the San Francisco Bay Area are summarized in Table 31, and within counties in Table 32.

TABLE 31

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

(In acres)

Hydrographic unit		Irrigated	Urban and suburban areas	Approximate total
Reference number	Name			
1	Marin-Sonoma	2,200	15,200	17,400
2	Napa Valley	2,600	9,200	11,800
3	Solano	8,300	1,500	9,800
4	Contra Costa	6,000	29,700	35,700
5	Livermore Valley	7,000	3,600	10,600
6	Alameda-Bayside	23,800	71,200	95,000
7	Santa Clara Valley	105,000	32,800	138,000
8	San Mateo-Bayside	2,400	33,700	36,100
9	San Mateo-Coastal	5,200	3,100	8,300
10	San Francisco	0	25,700	25,700
	Subtotals	163,000	225,000	388,000
	Unclassified areas receiving water service			50,000
	APPROXIMATE TOTAL			438,000

TABLE 32

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN COUNTIES, SAN FRANCISCO BAY AREA

(In acres)

County	Irrigated	Urban and suburban areas	Approximate total
Alameda	30,200	74,800	105,000
Contra Costa	6,700	29,700	36,400
Marin	600	8,900	9,500
Napa	2,600	4,400	7,000
San Francisco	0	25,700	25,700
San Mateo	7,600	36,800	44,400
Santa Clara	105,000	32,800	138,000
Santa Cruz	0	0	0
Solano	8,300	6,300	14,600
Sonoma	1,500	6,300	7,800
Subtotals	163,000	225,000	388,000
Unclassified areas receiving water service			50,000
APPROXIMATE TOTAL			438,000

PROBABLE ULTIMATE WATER SERVICE AREAS

To aid in estimating ultimate water requirements in the San Francisco Bay Area, projections were first made to determine the probable ultimate areal extent of irrigated crops and of urban and suburban types of land use. It was assumed that the remainder of the area, referred to as "other water service areas," will ultimately receive water service commensurate with its needs. Tidelands and other submerged lands were assumed to be reclaimed and developed to the most practicable use, and estimates were made both with and without such reclamation.

Tidelands and Submerged Lands Susceptible of Reclamation

The reclamation of tidelands and other submerged lands is a problem peculiar in California to the San Francisco Bay Area, with its many square miles of reclaimable lands bordering the great inland bays. In order to define the problem and establish standards for projecting ultimate development, three classifications of such lands were established. These classifications were:

Marshlands —Lands lying above ordinary high tide levels and supporting vegetation, but which are flooded by extreme high tides

Tidelands —Lands comprising barren mud flats lying between high and low tide levels, alternately covered and exposed by daily tidal fluctuations

Submerged lands—Lands lying below ordinary low tides, covered at all times by water of the bay

All marshlands were assumed to be susceptible of reclamation, generally for urban types of land use. It was further estimated that large areas of tidelands and submerged lands will, under conditions of ultimate development, be reclaimed.

Reclamation of tidal or submerged areas can best be accomplished with solid fills or levees constructed to appropriate elevations above high tide levels. Reclamation by solid fills results in costs which generally can only be justified by industrial, commercial, or similar uses of land. In the determination of susceptibility of marshes and tidelands to reclamation, it was assumed that reclamation would be effected by the construction of levees whenever feasible. Many successful projects for reclaiming tidal and submerged lands have been effected through levee construction. This method has been principally used in the Netherlands where large areas have been converted to productive lands through reclamation.

In a large portion of San Francisco, San Pablo, and Suisun Bays a flat, gently sloping bottom lies but a few feet below the water surface at low tide. Deep, relatively narrow channels with almost precipitous banks cut through this sloping floor of the bay. In most sections the edges of such channels lie less than 12 feet below mean lower low water. Areas susceptible of reclamation were assumed to extend approximately to the channel edges, where the bottom slopes change abruptly and further increments of reclaimable land can be enclosed only by excessive and uneconomic levee cross-sections. Exceptions to the general delineation of reclaimable areas were made, principally in San Pablo and Suisun Bays, in order to maintain sufficient main channel for accommodation of flood flows in the Sacramento and San Joaquin Rivers and to facilitate navigation.

Most of the levee construction required to effect reclamation would be built upon a base six feet or less below mean lower low water. At several locations, however, base elevations as great as 12 feet below mean lower low water would be necessary.

Pattern of Ultimate Development

The pattern of ultimate development in the San Francisco Bay Area was first projected on the assumption that no reclamation of tidelands would occur, and secondly, that all feasible tidal and submerged lands would be reclaimed. As stated heretofore, reclamation of marshlands was implicit in both assumptions. In both cases it was estimated for the area as a whole that the ultimate development on all habitable lands would be 95 per cent urban, and that the remaining lands would be devoted to irrigated agriculture. However, variations of this ratio were assumed for ultimate development in individual hydrographic units.

It was recognized that reclaimed areas would probably be principally occupied by industry and basic commercial activities, such as warehousing. It was also assumed that other urban activities, and irrigated agriculture, would expand into areas now vacant at such rates and in such amounts as to attain ultimately the proportional distribution set forth in the preceding paragraph.

Irrigated Lands

It was assumed that ultimately all lands in the San Francisco Bay Area that are suitable for irrigated agriculture, and not then occupied by urban and suburban developments, would be irrigated. Although no surveys were made to determine the locations of irrigable lands, the portion of the gross irrigable area that would ultimately be irrigated was estimated to be about five per cent of the total habitable area, after deductions were made for otherwise irrigable lands assumed to be ultimately urbanized. Of the ultimate gross irrigated area, an estimated two per cent represents lands expected to be occupied by farm lots, and an additional three per cent represents the included nonwater-using lands, such as roads, railroads, nonirrigable lands, etc. The remaining acreage represents the average area estimated to be actually irrigated each year under ultimate conditions of development. Table 33 lists the estimates of ultimate irrigated areas in hydrographic units of the San Francisco Bay Area, and Table 34 presents these data by counties.

To aid in estimating the probable ultimate water requirements, it was assumed that the irrigated lands would ultimately be devoted almost exclusively to truck crops, flower gardens and nurseries, dairies, and poultry farms. However, no detailed crop pattern was forecast.

TABLE 33

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Gross irrigated area	Farm lots	Included nonwater service area	Net irrigated area
1	Marin-Sonoma	8,500	200	300	8,000
2	Napa Valley	5,600	100	200	5,300
3	Solano	35,000	700	900	33,400
4	Contra Costa	0	0	0	0
5	Livermore Valley	12,300	200	400	11,700
6	Alameda-Bayside	1,200	100	----	1,100
7	Santa Clara Valley	1,900	100	100	1,700
8	San Mateo-Bayside	0	0	0	0
9	San Mateo-Coastal	1,300	100	----	1,200
10	San Francisco	0	0	0	0
	APPROXIMATE TOTALS	65,800	1,500	1,900	62,400

TABLE 34

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN COUNTIES, SAN FRANCISCO BAY AREA

(In acres)

County	Gross irrigated area	Farm lots	Included nonwater service area	Net irrigated area
Alameda	5,900	100	200	5,600
Contra Costa	0	0	0	0
Marin	0	0	0	0
Napa	5,600	100	200	5,300
San Francisco	0	0	0	0
San Mateo	1,300	100	----	1,200
Santa Clara	9,500	300	300	8,900
Santa Cruz	0	0	0	0
Solano	35,000	700	900	33,400
Sonoma	8,500	200	300	8,000
APPROXIMATE TOTALS	65,800	1,500	1,900	62,400

Urban and Suburban Water Service Areas

It is considered probable that the present trend of rapid urbanization in certain portions of the San Francisco Bay Area will continue in the future. In estimates for this bulletin, it was assumed that urban and suburban types of land use ultimately will occupy all lands in the Contra Costa, San Mateo-Bayside, and San Francisco Hydrographic Units, except those lands topographically unsuited for development. Consideration of present trends in Marin and Contra Costa Counties indicates that these regions will ultimately be urban in character.

Areas estimated to be ultimately occupied by the various urban land use types were determined by applying percentage factors to the determined ultimate

TABLE 35

PATTERNS OF PROBABLE ULTIMATE URBAN DEVELOPMENT WITHIN HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

(In per cent of gross urban area)

Urban classification	San Francisco Hydrographic Unit	Other hydrographic units
Residential		
Single	33.4	41.8
Multiple	7.2	3.3
Subtotals	40.6	45.1
Industrial, including airfields	7.3*	10.6*
Commercial	5.5	4.1
Institutions and parks		
Institutions	3.4	3.2
Parks	13.2	7.0
Subtotals	16.6	10.2
Area not requiring water service	30.0	30.0
TOTALS	100.0	100.0

* Does not include low water-using industrial area.

TABLE 36

PROBABLE ULTIMATE URBAN AND SUBURBAN AREAS WITHIN HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

(In acres)

Hydrographic unit		Without reclamation of tidelands								With reclamation of tidelands							
		Area requiring water service						Area not requiring water service	Approximate gross area	Area requiring water service						Area not requiring water service	Approximate gross area
Reference number	Name	Residential	Industrial: General	Industrial: Low water-using	Industrial: Air fields	Commercial	Institutions and parks			Residential	Industrial: General	Industrial: Low water-using	Industrial: Air fields	Commercial	Institutions and parks		
1	Marin-Sonoma	103,000	18,600	0	5,700	9,400	23,300	68,700	229,000	119,000	21,300	0	6,600	10,800	26,900	79,000	263,000
2	Napa Valley	52,200	9,400	8,800	2,900	4,700	11,800	34,800	125,000	60,400	10,800	8,800	3,300	5,500	13,600	40,200	143,000
3	Solano	55,500	9,900	0	3,100	5,000	12,500	37,000	123,000	60,000	10,800	0	3,300	5,500	13,600	40,000	133,000
4	Contra Costa	70,300	12,600	3,600	3,900	6,400	15,900	46,700	159,000	76,000	13,600	3,600	4,200	6,900	17,200	50,600	172,000
5	Livermore Valley	37,600	6,700	0	2,100	3,400	8,500	25,000	83,300	37,600	6,700	0	2,100	3,400	8,500	25,000	83,300
6	Alameda-Bayside	61,200	11,000	17,900	3,400	5,600	13,800	40,700	154,000	88,200	15,800	17,900	4,900	8,000	19,900	58,700	213,000
7	Santa Clara Valley	93,600	16,800	9,300	5,200	8,500	21,200	62,200	217,000	94,700	17,000	9,300	5,200	8,600	21,400	63,000	219,000
8	San Mateo-Bayside	40,500	7,300	7,600	2,200	3,700	9,200	26,900	97,400	49,600	8,900	7,600	2,800	4,500	11,200	33,000	118,000
9	San Mateo-Coastal	15,500	2,700	0	900	1,400	3,500	10,300	34,300	15,500	2,700	0	900	1,400	3,500	10,300	34,300
10	San Francisco	11,600	2,100	0	0	1,600	4,700	8,600	28,600	12,000	2,200	0	0	1,600	4,900	8,800	29,500
	APPROXIMATE TOTALS	541,000	97,100	47,200	29,400	49,700	124,000	361,000	1,250,000	613,000	110,000	47,200	33,300	56,200	141,000	408,000	1,408,000

TABLE 37

PROBABLE ULTIMATE URBAN AND SUBURBAN AREAS WITHIN COUNTIES, SAN FRANCISCO BAY AREA

(In acres)

County	Without reclamation of tidelands								With reclamation of tidelands							
	Area requiring water service						Area not requiring water service	Approximate gross area	Area requiring water service						Area not requiring water service	Approximate gross area
	Residential	Industrial: General	Industrial: Low water-using	Industrial: Air fields	Commercial	Institutions and parks			Residential	Industrial: General	Industrial: Low water-using	Industrial: Air fields	Commercial	Institutions and parks		
Alameda	92,700	16,600	17,900	5,200	8,400	21,000	61,700	224,000	120,000	21,400	17,900	6,700	10,900	27,000	79,700	283,000
Contra Costa	76,300	13,700	3,600	4,200	6,900	17,300	50,800	173,000	82,000	14,700	3,600	4,500	7,500	18,600	54,600	186,000
Marin	54,000	9,700	0	3,000	4,900	12,200	36,000	120,000	58,000	10,400	0	3,200	5,300	13,100	38,600	129,000
Napa	44,000	7,900	8,800	2,500	4,000	10,000	29,300	106,000	44,000	7,900	8,800	2,500	4,000	10,000	29,300	106,000
San Francisco	11,600	2,100	0	0	1,600	4,700	8,600	28,600	12,000	2,200	0	0	1,600	4,900	8,800	29,500
San Mateo	56,000	10,100	7,600	3,100	5,100	12,700	37,100	132,000	65,100	11,700	7,600	3,600	5,900	14,700	43,300	152,000
Santa Clara	93,600	16,800	9,300	5,200	8,500	21,100	62,300	217,000	94,700	17,000	9,300	5,200	8,600	21,400	63,000	219,000
Santa Cruz	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Solano	63,700	11,400	0	3,500	5,800	14,300	42,490	141,000	76,400	13,600	0	4,200	6,900	17,300	50,900	169,000
Sonoma	49,300	8,800	0	2,700	4,500	11,100	32,700	109,000	60,800	10,900	0	3,400	5,500	13,700	40,400	135,000
APPROXIMATE TOTALS	541,000	97,100	47,200	29,400	49,700	124,000	361,000	1,250,000	613,000	110,000	47,200	33,300	56,200	141,000	408,000	1,408,000

gross urban and suburban area, the factors being based upon present urban land use patterns and expected future changes. Table 35 presents the factors used in the estimate of ultimate urban development.

In the determination of probable ultimate water service areas, the area occupied by farm lots was included as a portion of the gross irrigable area.

In the determination of ultimate land use, certain assumptions were made as to the ultimate disposition of lands presently occupied by military reservations. All such areas presently existing were included within urban classifications. Water requirements within military reservations are generally less, on a gross acreage basis, than in other urban classifications. The estimates of ultimate gross water requirements in these areas, therefore, should be generally conservative, dependent upon the degree of change in land use due to establishment or abandonment of defense installations.

Table 36 presents the probable ultimate pattern of land use in urban and suburban water service areas in hydrographic units of the San Francisco Bay Area, and Table 37 presents the probable ultimate gross urban and suburban areas in counties of the area.

Other Water Service Areas

The remaining 1,222,000 acres of the San Francisco Bay Area, not included in either the ultimate irrigated or urban and suburban water service areas, were not classified in detail regarding the nature of their probable ultimate water service. It was assumed that these "other water service areas" will include developed areas within the national and state parks, state beaches, and scattered recreational, residential, and industrial developments not included in the ultimate urban and suburban water service area. The greatest portion of these lands are in areas topographically or otherwise unsuitable for intensive development. Other water service areas within hydrographic units and within counties are presented in Table 38.

Summary

Table 39 presents a summary of probable ultimate water service areas, segregated into irrigated, urban and suburban, and other water service areas.

TABLE 38

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, SAN FRANCISCO BAY AREA

(In acres)

Location: Hydrographic unit — Reference number	Name	Approximate gross area
1	Marin-Sonoma	198,000
2	Napa Valley	135,000
3	Solano	61,800
4	Contra Costa	77,900
5	Livermore Valley	310,000
6	Alameda-Bayside	64,200
7	Santa Clara Valley	236,000
8	San Mateo-Bayside	18,000
9	San Mateo-Coastal	120,000
10	San Francisco	600
	APPROXIMATE TOTAL	1,222,000
County		
Alameda		202,000
Contra Costa		116,000
Marin		136,000
Napa		163,000
San Francisco		600
San Mateo		134,000
Santa Clara		371,000
Santa Cruz		3,400
Solano		33,900
Sonoma		61,900
APPROXIMATE TOTAL		1,222,000

TABLE 39

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS, SAN FRANCISCO BAY AREA

(In acres)

Hydrographic unit		Without reclamation of tidelands				With reclamation of tidelands			
Reference number	Name	Irrigated lands	Urban and suburban areas	Other water service areas	Approximate total	Irrigated lands	Urban and suburban areas	Other water service areas	Approximate total
1	Marin-Sonoma	8,500	229,000	198,000	436,000	8,500	263,000	198,000	470,000
2	Napa Valley	5,600	125,000	135,000	266,000	5,600	143,000	135,000	284,000
3	Solano	35,000	123,000	61,800	220,000	35,000	133,000	61,800	230,000
4	Contra Costa	0	159,000	77,900	237,000	0	172,000	77,900	250,000
5	Livermore Valley	12,300	83,300	310,000	406,000	12,300	83,300	310,000	406,000
6	Alameda-Bayside	1,200	154,000	64,200	219,000	1,200	213,000	64,200	278,000
7	Santa Clara Valley	1,900	217,000	236,000	455,000	1,900	219,000	236,000	457,000
8	San Mateo-Bayside	0	97,400	18,000	115,000	0	118,000	18,000	136,000
9	San Mateo-Coastal	1,300	34,300	120,000	155,000	1,300	34,300	120,000	155,000
10	San Francisco	0	28,600	600	29,200	0	29,500	600	30,100
	APPROXIMATE TOTALS	65,800	1,250,000	1,222,000	2,538,000	65,800	1,408,000	1,222,000	2,696,000

UNIT VALUES OF WATER USE

Unit seasonal values of water use in the San Francisco Bay Area were determined in accordance with the methods and procedures described in Chapter II. Unit values of urban water use were based upon special studies conducted in various communities of the area by the East Bay Municipal Utility District and the San Francisco Water Department. Data employed in determination of unit values of water use for irrigated crops included the results of studies conducted by various public agencies.

Irrigation Water Use

Unit seasonal values of consumptive use of water by irrigated crops were, in general, determined in accordance with the methods of Chapter II. Estimated unit seasonal values of consumptive use of applied irrigation water and of precipitation by various crop groups are presented in Table 40. The probable mean seasonal consumptive use of water on lands ultimately to be irrigated was estimated by applying the unit value of water use for truck crops, considered representative of average unit use for all irrigated crops, to the net irrigated acreage.

Urban and Suburban Water Use

The unit seasonal value of consumptive use of water in urban and suburban developments is influenced largely by geographic and geologic aspects of the developed area. In a large part of the San Francisco Bay Area, present urban developments overlie either bedrock or impervious materials which prevent percolation of water to any underlying bodies of ground water. Additionally, the sewage outflow is discharged to San Francisco Bay from much of the urban area overlying free ground water. In these areas, the consumptive use of applied water was considered to be equivalent to the unit net delivery of water, as only minor ground water recharge from the applied water occurs.

In the determination of present water requirements in the free ground water zones of Livermore and Santa Clara Valleys, ground water recharge from the present urban area was estimated as a separate quantity. The entire urban and suburban development in the San Francisco Bay Area was assumed to be sewered under conditions of probable ultimate development, and no recharge to underlying ground water from this source was considered to occur.

Present unit values of consumptive use of applied water were determined for most types of urban land use from studies of data collected in extensive field sampling of actual water deliveries to consumers in each land use classification. The sampling procedures employed are discussed in Chapter II. The estimated values where records of deliveries were not available were based upon estimates of consumptive use on similar areas in other parts of California.

Ultimate unit values of consumptive use of applied water were obtained by modifying present values in certain classifications to account for indicated trends. In this connection, a study of historical trends was made in the City of San Francisco on a basis of use of water per acre, and in the distribution areas of several other large water service agencies on a basis of per capita use. However, the results of this study were unsatisfactory, as it was not possible to derive a maximum limitation on the ultimate unit value of use of applied water.

In view of the foregoing, assumptions were made concerning future increases in values of water use on various urban types, and with regard to eventual land use practices in different hydrographic units. It was estimated that increasing use of modern water-using appliances, such as automatic washers and garbage

TABLE 40

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, SAN FRANCISCO BAY AREA

(In feet of depth)

Hydrographic unit		Alfalfa			Pasture			Beans			Flowers			Grain			Orchard, almond-prunes		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Marin-Sonoma	2.0	1.6	3.6	2.1	1.3	3.4	----	----		----	----	----	1.0	1.2	2.2	1.1	1.4	2.5
2	Napa Valley	----	----	----	2.1	1.3	3.4	----	----		----	----	----	1.0	1.2	2.2	1.1	1.4	2.5
3	Solano	----	----	----	2.4	1.2	3.6	----	----	----	----	----	----	1.0	1.2	2.2	1.3	1.3	2.6
4	Contra Costa	----	----	----	2.3	1.2	3.5	----	----	----	0.8	1.1	1.9	1.1	1.2	2.3	1.3	1.3	2.6
5	Livermore Valley	2.4	1.3	3.7	2.3	1.2	3.5	0.4	1.2	1.6	1.1	1.1	2.2	0.9	1.2	2.1	1.3	1.3	2.6
6	Alameda-Bayside	2.1	1.5	3.6	2.1	1.2	3.3	0.6	1.2	1.8	0.7	1.2	1.9	1.0	1.2	2.2	1.2	1.3	2.5
7	Santa Clara Valley	2.1	1.5	3.6	2.2	1.2	3.4	0.7	1.1	1.8	----	----	----	1.0	1.2	2.2	1.2	1.3	2.5
8	San Mateo-Bayside	2.2	1.5	3.7	2.1	1.3	3.4	----	----	----	0.7	1.2	1.9	1.1	1.1	2.2	----	----	----
9	San Mateo-Coastal	1.9	1.5	3.4	1.9	1.2	3.1	0.5	1.2	1.7	0.5	1.2	1.7	0.8	1.2	2.0	----	----	----
10	San Francisco	----	----	----	----	----	----	----	----	----	----	----	----			----	----	----	----

TABLE 40—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, SAN FRANCISCO BAY AREA

(In feet of depth)

Hydrographic unit		Orchard, walnut			Orchard, other deciduous			Sugar beets			Truck			Vineyard		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Marin-Sonoma	1.6	1.4	3.0	1.4	1.4	2.8	-----	-----	-----	1.1	1.2	2.3	0.9	1.2	2.1
2	Napa Valley	1.7	1.4	3.1	-----	-----	-----	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
3	Solano	1.8	1.2	3.0	1.7	1.3	3.0	-----	-----	-----	1.2	1.2	2.4	1.1	1.1	2.2
4	Contra Costa	1.9	1.2	3.1	1.7	1.2	2.9	-----	-----	-----	1.2	1.2	2.4	1.0	0.9	1.9
5	Livermore Valley	1.9	1.2	3.1	1.7	1.2	2.9	1.2	1.2	2.4	1.1	1.1	2.2	1.0	1.1	2.1
6	Alameda-Bayside	1.7	1.3	3.0	1.5	1.3	2.8	1.1	1.2	2.3	1.1	1.2	2.3	0.9	1.2	2.1
7	Santa Clara Valley	1.2	1.3	2.5	1.2	1.3	2.5	1.2	1.1	2.3	1.2	1.1	2.3	0.9	1.2	2.1
8	San Mateo-Bayside	1.7	1.4	3.1	1.6	1.3	2.9	-----	-----	-----	1.0	2.0	3.0	-----	-----	-----
9	San Mateo-Coastal	-----	-----	-----	1.3	1.3	2.6	-----	-----	-----	1.1	1.7	2.8	-----	-----	-----
10	San Francisco	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----

disposal units, would result in an ultimate residential use per acre of some 15 per cent greater than at present. Unit values of present multiple residential use of water were found to differ in the various hydrographic units, being exceptionally high in the San Francisco Hydrographic Unit. With the exception of this hydrographic unit, therefore, it was assumed that the ultimate multiple residential use would be the same in all hydrographic units, and 15 per cent greater than the highest present use. It was further assumed that in the San Francisco Hydrographic Unit ultimate multiple residential unit use of water would be 15 per cent greater than the present relatively high value.

In hydrographic units which at present have a relatively minor degree of industrial development, ultimate unit values of water use for the industrial classification were generally assumed to be the same as the present value in the more intensively developed areas. In those hydrographic units presently somewhat more highly developed, adjustments were made in the unit values of use of applied water where it was believed that the distribution of industry would change in the future.

In the remaining classes of land use, including commercial, airfields, irrigated parks, and institutions, the ultimate unit values of use of applied water were assumed to be equal to the present values.

The present and probable ultimate values of net delivery of applied water in urban and suburban areas are presented in Table 41. Weighted mean unit values applicable to net urban and suburban water service areas within hydrographic units are also presented in Table 41. This table indicates that the prob-

TABLE 41

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL UNIT VALUES OF WATER DELIVERY IN URBAN AND SUBURBAN AREAS, SAN FRANCISCO BAY AREA

(In feet of depth)

Hydrographic unit		Residential				Industrial				Commercial		Institutions		Irrigated parks		Weighted mean*	
		Single		Multiple		General		Airfield									
Reference number	Name	Present	Ultimate	Present	Ultimate	Present	Ultimate	Present	Ultimate	Present	Ultimate	Present	Ultimate	Present	Ultimate	Present	Ultimate
1	Marin-Sonoma	2	2.3	7	8.1	6	7	0.4	0.4	4	4	2	2	1	1	2.3	3.0
2	Napa Valley	2	2.3	4	8.1	4	8	0.4	0.4	4	4	2	2	1	1	2.1	2.8
3	Solano	2	2.3	4	8.1	4	8	0.4	0.4	4	4	2	2	1	1	2.0	3.1
4	Contra Costa	2	2.3	6	8.1	19	14	0.4	0.4	4	4	2	2	1	1	5.5	3.7
5	Livermore Valley	2	2.3	4	8.1	45	8	0.4	0.4	4	4	2	2	1	1	3.6	3.1
6	Alameda-Bayside	2	2.3	7	8.1	9	9	0.4	0.4	4	4	2	2	1	1	2.0	2.7
7	Santa Clara Valley	2	2.3	6	8.1	8	9	0.4	0.4	4	4	2	2	1	1	1.8	3.0
8	San Mateo-Bayside	2	2.3	7	8.1	8	8	0.4	0.4	4	4	2	2	1	1	1.6	2.8
9	San Mateo-Coastal	2	2.3	7	8.1	2	2	0.4	0.4	4	4	2	2	1	1	1.7	2.4
10	San Francisco	4	4.6	15	17.3	6	6	-----	-----	10	10	2	2	1	1	5.1	5.7
	WEIGHTED MEAN	2.2	2.3	9.8	8.5	11.1	8.7	0.4	0.4	5.2	4.2	2.0	2.0	1.0	1.0	2.7	3.1

NOTE: Water delivery assumed equivalent to consumptive use of applied water.
* Includes low water-using industrial areas at zero depth.

able ultimate weighted mean unit values of consumptive use of urban water will not be significantly greater than present values. Estimated increases in single-family residential use will be offset by decreases in other urban water use classifications. Particularly in some hydrographic units, it was assumed that in the future there would be a wider range of the types of industry than occurs at present, resulting in a decrease in the average unit water use value for industry.

Use of Water in Other Water Service Areas

Unit values of water use on lands requiring water service, but not included in the irrigated or urban and suburban water service areas, were derived generally from measured or estimated present deliveries of water to typical areas involved, or from records and estimates of per capita use of water. Since the quantity of water involved is small, and since recovery of return flow is generally negligible, total deliveries were considered to be consumptively used.

The present mean seasonal unit delivery of water to farm lots was considered to be equivalent to the consumptive use of applied water, except in free ground water zones, where recharge was determined separately. Both present and ultimate unit values of delivery of water to farm lots were estimated to be equivalent to a depth of two feet per season.

The present value of unit water delivery to military areas was not determined. Instead, records of metered total annual delivery to all installations were obtained. Although a large percentage of military lands lay idle during 1949, it was assumed that under conditions of ultimate development substantially all military lands will have been developed, either by military authorities or by private enterprise. It was further estimated that this development would result in requirements equivalent to those of a similar acreage of balanced urban development.

Unit values of probable ultimate water use on scattered residential, industrial, and recreational developments were determined on the basis of estimated population densities varying from 5 to 40 persons per square mile, and per capita water use of 70 gallons per day. These factors were employed in estimating the ultimate requirement of unclassified areas, and this requirement was considered to be equivalent to the consumptive use of applied water. The negligible aggregate water requirement resulting from these assumptions was not considered in determining supplemental water requirements for the San Francisco Bay Area.

CONSUMPTIVE USE OF WATER

Consumptive use of water in water service areas of the San Francisco Bay Area was generally determined by applying appropriate unit seasonal values of consumptive use to estimated areas occupied either by crops or by urban and suburban classes of land use. Estimates of seasonal consumptive use of applied water and precipitation in present water service areas are given in Table 42.

TABLE 42

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, SAN FRANCISCO BAY AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Urban and suburban areas	Unclassified areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	
1	Marin-Sonoma	3,700	2,800	15,000	4,200	22,900
2	Napa Valley	3,800	3,300	12,400	5,200	21,400
3	Solano	13,000	10,700	2,000	3,600	18,600
4	Contra Costa	9,700	7,100	85,200	2,700	97,600
5	Livermore Valley	10,100	8,200	3,500	2,300	15,900
6	Alameda-Bayside	30,800	29,600	85,800	5,700	122,000
7	Santa Clara Valley	130,000	133,000	39,500	5,200	175,000
8	San Mateo-Bayside	2,000	3,800	28,700	500	31,200
9	San Mateo-Coastal	5,500	8,400	2,700	1,200	9,400
10	San Francisco	0	0	77,600	5,000	82,600
	APPROXIMATE TOTALS	209,000	207,000	352,000	35,600	597,000

Table 43 presents corresponding estimates for probable ultimate conditions of development. These estimates represent the seasonal values under mean conditions of water supply and climate.

The consumptive use estimates for urban and suburban and unclassified areas represent the gross delivery of water to lands so classified. Ultimate consumptive use of water on all irrigated lands was assumed to be equivalent to the estimated use of water by truck crops, as heretofore stated.

During the course of the studies made for the present bulletin, considerable data relative to the distribution of gross urban water requirements were developed. These data, grouped by land use classification, are presented in Table 44.

FACTORS OF WATER DEMAND

In the planning of water conservation projects and accompanying distribution systems, certain factors in addition to consumptive use of water must be given consideration. Among these factors are necessary rates, times, and places of delivery, quality of water, losses of water, soil conditions, etc. The most important of these factors in the San Francisco Bay Area are those associated with the supply of water for urban use, and include system water losses and seasonal distribution of urban water demands.

TABLE 43

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, SAN FRANCISCO BAY AREA

(In acre-feet)

Hydrographic unit		Without reclamation of tidelands						With reclamation of tidelands					
Reference number	Name	Irrigated lands		Farm lots	Urban and suburban areas	Other water service areas	Approximate total consumptive use of applied water	Irrigated lands		Farm lots	Urban and suburban areas	Other water service areas	Approximate total consumptive use of applied water
		Applied water	Precipitation	Applied water	Applied water	Applied water		Applied water	Precipitation	Applied water	Applied water	Applied water	
1	Marin-Sonoma	8,800	9,600	400	482,000	400	492,000	8,800	9,600	400	552,000	400	562,000
2	Napa Valley	5,800	6,400	200	253,000	100	259,000	5,800	6,400	200	292,000	300	298,000
3	Solano	40,100	40,100	1,400	268,000	100	310,000	40,100	40,100	1,400	291,000	0	332,000
4	Contra Costa	0	0	0	416,000	400	416,000	0	0	0	449,000	400	449,000
5	Livermore Valley	12,900	12,900	400	182,000	200	195,000	12,900	12,900	400	182,000	200	195,000
6	Alameda-Bayside	1,200	1,300	100	308,000	400	310,000	1,200	1,300	100	443,000	300	445,000
7	Santa Clara Valley	2,000	1,900	200	470,000	700	473,000	2,000	1,900	200	476,000	800	479,000
8	San Mateo-Bayside	0	0	0	196,000	100	196,000	0	0	0	240,000	100	240,000
9	San Mateo-Coastal	1,200	2,000	100	58,200	100	59,600	1,200	2,000	100	58,200	100	59,600
10	San Francisco	0	0	0	114,000	0	114,000	0	0	0	117,000	0	117,000
	APPROXIMATE TOTALS	72,000	74,200	2,800	2,747,000	2,500	2,824,000	72,000	74,200	2,800	3,100,000	2,600	3,177,000

At present, irrigation water demand factors are only slightly less important than those related to urban requirements. It is anticipated that in the future, as urban development expands into the irrigable lands of the San Francisco Bay Area, irrigation water demand factors will decrease correspondingly in importance.

The water demand factors most pertinent to water utilization and requirements of the San Francisco Bay Area are briefly discussed in the following sections.

TABLE 44

DISTRIBUTION OF URBAN WATER DELIVERIES BY LAND USE CLASSIFICATIONS, SAN FRANCISCO BAY AREA

(In per cent)

Land use classification	Water deliveries	
	Present	Ultimate
Residential		
Single	36.9	42.7
Multiple	12.9	12.6
Subtotals	49.8	55.3
Industrial, including airfields	36.6*	31.3*
Commercial	8.5	7.5
Institutions and parks		
Institutions	2.5	2.8
Parks	2.6	3.1
Subtotals	5.1	5.9
TOTALS	100.0	100.0

* Does not include low water-using industrial areas.

Losses in Urban Water Utility Systems

Analysis of available records of urban water production and metered delivery resulted in determinations of transmission and distribution losses, expressed as per cent of production, of from 5.5 per cent to 21 per cent. However, a majority of the system losses, including those of all major water systems, fell within a range of 8 to 12 per cent of production. Based on these findings, a value of 10 per cent of net delivery of water was estimated as representing a reasonable allowance for both present and ultimate system losses of water. It is believed that there will not be a significant difference in present and ultimate system losses.

Distribution of Urban Water Demands

An analysis of records covering 77 per cent of the total estimated 1949 delivery of water to urban areas resulted in the determination of monthly demands as presented in Table 45. These values were determined principally from weighted mean percentages of monthly deliveries of water in urban areas of the San Francisco Water Department, East Bay Municipal Utility District, Contra Costa County Water District, San Jose Water Works, Marin Municipal Water District, and Vallejo Municipal Water Works. Deliveries of water in Napa, Suisun, Fairfield, Mountain View, Sunnyvale, Benicia, Petaluma, and Sonoma were also included, as were the monthly requirements of the Sonoma State Home, Veterans Home of California, and Travis Air Force Base.

The mean seasonal distribution of monthly irrigation water demand, based upon records of agricultural power sales over a period of five years in the

North Bay, East Bay, and San Jose Divisions of the Pacific Gas and Electric Company, is also presented in Table 45.

TABLE 45

AVERAGE DISTRIBUTION OF MONTHLY WATER DEMANDS, SAN FRANCISCO BAY AREA

(In per cent of seasonal total)

Month	Urban demand	Irrigation demand
January	7.0	0.0
February	6.4	0.8
March	7.0	1.3
April	8.1	2.6
May	8.8	8.8
June	10.0	17.9
July	10.2	18.4
August	10.1	15.2
September	9.6	17.4
October	8.7	12.2
November	7.2	4.6
December	6.9	0.8
TOTALS	100.0	100.0

Irrigation Water Service Area Efficiency

Water requirements in the San Francisco Bay Area were determined from consideration of total water application in each hydrographic unit, consumptive use of applied water, subsequent re-use of a portion of the applied water, losses associated with conveyance of water to places of use, and the final loss by discharge to the ocean. The effect of irrecoverable losses upon the water requirements may be measured by the water service area efficiency, defined as the ratio of consumptive use of applied water in a service area to the gross amount of water delivered to the area. Irrigation water service area efficiencies were estimated for each hydrographic unit of the San Francisco Bay Area.

Irrigation efficiency is defined as the ratio of consumptive use of applied water to the total amount of water applied to irrigated crops. In the San Francisco Bay Area there are significant variations in irrigation efficiency, dependent upon crop, soil type, topographic characteristics, cost and availability of water, and local irrigation practice. Generally throughout the area, present irrigation efficiencies average about 50 per cent. This factor was applied without adjustment in the areas overlying ground water pressure zones, where the excess application does not return to storage in the subsurface aquifers. In free ground water zones, the re-use of water made possible by its return to ground water through percolation results in the attainment of relatively higher efficiencies. The ground water recharge in each hydrographic unit was estimated by determining the effective absorptive area occupied by agricultural development and computing the probable recharge therefrom. The total net irrigation requirement in free ground water zones was estimated by subtracting this value for ground water recharge from the amount of the gross application of water necessary in accordance with the indicated 50 per cent efficiency factor.

Abundant supplies of surface water are not available for most irrigated localities in the San Francisco Bay Area. Virtually all water supplies utilized for irrigation are pumped from ground water basins, in several of which the indications of overdraft are evident. It is anticipated that increased demands on the limited local supplies will operate in the future to enforce greater economy in the application of water for irrigation. This factor, together with probable increased costs for development of supplemental water supplies, should result in a material increase in future irrigation efficiency. The ultimate irrigation water requirements in pressure zones were estimated by assuming an eventual irrigation efficiency of 70 per cent. Probable ground water recharge in free ground water zones was estimated in the same manner as for present conditions, assuming, however, an irrigation efficiency of 70 per cent.

Table 46 presents estimated irrigation water service area efficiencies under present and probable ultimate conditions of development. It should be noted that water service area efficiencies ultimately attained will be dependent in great part on plans for ultimate water service, and on the extent to which return flow from irrigated lands and urban areas can be regulated and re-used. For this reason the predictions may be subject to appreciable changes as planning continues.

TABLE 46

ESTIMATED WEIGHTED MEAN IRRIGATION WATER SERVICE AREA EFFICIENCY WITHIN HYDROGRAPHIC UNITS, SAN FRANCISCO BAY AREA

(In per cent)

Hydrographic unit		Present	Probable ultimate
Reference number	Name		
1	Marin-Sonoma	60	70
2	Napa Valley	60	70
3	Solano	55	70
4	Contra Costa	50	—
5	Livermore Valley	85	90
5	Alameda-Bayside	50	70
7	Santa Clara Valley	85	85
8	San Mateo-Bayside	50	—
9	San Mateo-Coastal	50	70
10	San Francisco	—	—
	WEIGHTED MEAN	65	75

WATER REQUIREMENTS

Water requirements, as the term is used in this bulletin, refer to the amounts of water needed to provide for all beneficial uses of water and for any irrecoverable losses incidental to such uses. Certain requirements for water which are basically nonconsumptive in nature are discussed briefly in the following section in general terms. Following this, water requirements of a consumptive nature are evaluated for both present and probable ultimate conditions of development.

Requirements of a Nonconsumptive Nature

The principal nonconsumptive water requirements of the San Francisco Bay Area are those pertaining to flood control, preservation and propagation of fish and wildlife, repulsion of sea water from ground water basins, and salt balance in irrigated areas. Navigation is restricted to various arms of the bay and to tidal channels of some of the tributary streams.

In general, the fresh-water outflow provided from the Central Valley Area for salinity control, navigation, maintenance and propagation of fish life, and for other purposes, will provide for all necessary fresh-water nonconsumptive uses in the San Francisco Bay Area. It is anticipated that future developments will not result in any fresh-water requirement for these purposes.

This bulletin does not evaluate the quantities of water involved in satisfying these nonconsumptive requirements, since these quantities in many instances are dependent upon the evolution of definite plans for the development of water resources. Their consideration herein is limited to discussion of their implications as related to planning for future water resource development.

Flood Control. The San Francisco Bay Area is characterized by flood problems which are principally of a local nature. Most of the presently existing development has taken place on land of sufficient slope to prevent accumulation of flood waters or in areas not under the influence of large flood-producing streams. There are, however, some areas where serious inundations have taken place. Marshlands at the mouths of most of the streams entering the bay are covered by high water in almost all years. High tides in these regions also contribute to the hazard of flood damages. Flood problems are somewhat less severe inland from the bay and ocean. Reservoirs on several streams, notably Coyote Creek and the tributaries of the Guadalupe River, provide incidental flood protection as a result of the impounding of water supplies for conservation.

Levee systems have been built on the lower reaches of most of the larger streams of the San Francisco Bay Area, but they have not been as effective in reducing flood damage as had been expected, principally due to the recent intensive urban development in the affected areas.

Several flood control and water conservation districts have been organized in the area, and the formation of others is under consideration. Such districts complement the work of the Corps of Engineers in the planning, construction, and operation of flood control works throughout the San Francisco Bay Area. Most additional works presently contemplated consist of channel improvements, storm drains, and detention reservoirs of small capacity in the tributary drainage basins.

Additional urbanization in the San Francisco Bay Area will create drainage and storm-water problems that will require consideration in future planing, and the construction of flood-protection works.

Fish and Wildlife. The San Francisco Bay Area is limited with regard to fresh-water sport fishing, but the marine and brackish waters of the area support both sport and commercial fisheries of considerable importance.

The principal commercial fishes are king salmon, shad, and Pacific herring. Salmon and shad migrate through San Francisco Bay into the Central Valley for spawning purposes, while Pacific herring spawn in San Francisco Bay. A commercial fishery of some importance for shrimp also exists in the bay. The combined landings of these species amount to an annual quantity of several million pounds.

The principal sport fish of the area is the striped bass, which is taken mainly in the bays and brackish waters of the numerous sloughs and channels. Large runs of steelhead rainbow trout use the bays and delta as a passageway from the ocean to the streams of the interior valley, although very little angling for them takes place in the marine and brackish waters. Steelhead trout also migrate into several of the local streams tributary to San Francisco and San Pablo Bays, such as San Francisquito, Stevens, Coyote, and Alameda Creeks, and the Napa River. Steelhead trout move annually from the ocean into several of the coastal streams of San Mateo County, including Pescadero and San Gregorio Creeks. The leading stream fishery of the area is that for the adult steelhead trout. Trout form resident populations in some of the streams, and along with the young steelhead contribute to the fishery. Silver salmon migrate from the ocean into suitable streams in the area, principally Pescadero and San Gregorio Creeks, and provide some sport fishing.

Several lakes in the San Francisco Bay Area are stocked with trout, including Phoenix Lake, Lagunitas, Alpine, Bon Tempe, Stevens Creek, and Lexington Reservoirs, and Merced, Madigan, and Frey Lakes. Warm-water game fishes, including the black basses, sunfishes, crappies, and catfishes, are present in a number of farm ponds and small reservoirs. Largemouth black bass are present in parts of the Napa River. Reservoirs stocked with warm-water game fishes include Anderson, Calero, and Coyote.

For large numbers of anadromous fishes, the salt and brackish waters of the bay serve as an entryway to spawning grounds. Sport and commercial fishing in the San Francisco Bay Area are sustained primarily by these migrations. Fresh-water demands of anadromous fisheries are a consideration in the Central Valley Area, and do not constitute an additional demand on the local water supplies of the San Francisco Bay Area.

It is considered doubtful that the limited water resources of the San Francisco Bay Area can meet additional water requirements for the preservation and enhancement of fish life, except when such requirements do not decrease supplies available to meet consumptive requirements. This does not, however, signify that fisheries will not benefit by future water development, particularly by importation of water from outside sources. Reservoirs created to impound water will provide additional habitat for game fish populations. Water released in stream beds for downstream requirements will, if the water is drawn from the deeper parts of the reservoir, provide conditions suitable for the development of trout fisheries. It is necessary only to provide minimum pool elevations in the reservoirs, and assure public access to the created waters, to realize fisheries benefits from water development in the San Francisco Bay Area.

At present, virtually all water demands of migratory waterfowl that frequent the marshy areas of the bays are supplied from salt and brackish waters. It is anticipated that the same condition will prevail under ultimate conditions, and that the fresh-water demand will be insignificant.

Repulsion of Salt-Water Intrusion From Ground Water Basins. In portions of the San Francisco Bay Area directly bordering the southern shores of the bay, intrusion of saline water into shallow aquifers has become a serious problem. In the area of southern Alameda County centered about Niles, Irvington, and Centerville, salt-water intrusion is a present critical source of damage. There is danger of degradation of water supplies in deeper confined aquifers by contamination from overlying shallow strata. This may occur through natural or man-made fissures in the confining blanket, abandoned or defective wells, or by possible intrusion of salt water from the bay if present pumping rates, whereby depression of the hydraulic gradient occurs to the extent that a landward slope results, should continue to prevail in the future. In view of the extensive use being made of this source of ground water supply at the present time, the prospect of such degradation is very serious. Except in a few local areas, however, such as at the edge of the confining blanket in the Niles Cone region, the quality of water in the lower aquifer has so far remained satisfactory.

Intrusion of salt water may be prevented by maintaining pressure levels in these basins at elevations above sea level. Determination of the quantities of water required to prevent sea-water intrusion will be dependent upon specific plans of development and pumping draft. However, it appears that a substantial amount of water will be unavoidably lost by outflow under such conditions, particularly from areas in Santa Clara and Alameda Counties adjacent to the bay. Studies conducted by the Division of Water Resources in Alameda County indicate that if pumpage from the presently overdrawn ground water basins underlying the Niles Cone area were limited to the safe yield of the basins, intrusion of salt water from the bay would be eliminated.

Other areas of possible saline intrusion which have been studied by the United States Geological Survey in cooperation with the Division of Water Resources are the Clayton and Ygnacio Basins in northern Contra Costa County, the Fairfield region in Solano County, and the Napa-Sonoma and Petaluma Basins bordering San Pablo Bay. In part of the Fairfield region, pressure levels approximately 20 feet below sea level are indicative of possible imminent intrusion of water from the bay. In the Napa-Sonoma Basin, there is evidence that natural and man-made breaks in the confining clay layers, and abandoned or defective wells, have produced local pollution from overlying brackish and saline sloughs.

Salt Balance. Local irrigation water supplies in the San Francisco Bay Area are, for the most part, obtained by pumping from ground water storage. The estimates of requirements for water which are subsequently set forth are predicated upon utilization of ground water storage capacity so as to facilitate the re-use of local and imported water applied to lands in excess of requirements for consumptive use. Natural replenishment of many ground water basins in the San Francisco Bay Area is derived from surface drainage from tributary watersheds, and to a limited extent from subsurface outflow from upstream basins. The mineral quality of the ground water contained in these basins must be protected from deterioration in order to maintain the utility of the storage capacity. This will require sufficient drainage from each basin to remove a quantity of dissolved salts equivalent to the amount of salt input to the basin. Quantitative estimates of the amount of water required for this purpose will necessarily depend upon the formulation of specific plans for future development in each instance.

Requirements of a Consumptive Nature

Requirements for water represent the quantities of water, other than precipitation, which must be supplied to provide for beneficial consumptive use of water on irrigated lands, urban and suburban areas, and other water service areas, and to provide for irrecoverable losses incidental to such use. Present and probable ultimate water requirements in the San Francisco Bay Area were determined by use of the previously derived estimates of total water application and consumptive use of applied water, giving consideration to the possible re-use of a portion of the applied water and to losses incurred in conveyance to the place of use.

In general it was assumed that, in irrigated water service areas overlying or immediately adjacent to major free ground water basins, re-use of all water applied in excess of consumptive use could be accomplished. The irrigation water requirement for such areas was therefore taken as equal to the consumptive use of applied water. In water service areas adjacent to the bay or overlying confined aquifers, it was assumed that no re-use of applied water could be effected in excess of consumptive use. The irrigation water requirement in such cases was assumed to be equal to the total water applied plus irrecoverable conveyance losses.

Urban and suburban water requirements were evaluated in the same general manner as those for irrigated lands, except that consideration was given to the effect of sewerage facilities with ocean discharge on requirements in those urban areas overlying free ground water basins. The present water requirement for these urban areas was estimated as the sum of the consumptive use of applied water, present export to the ocean of sewage, and irrecoverable conveyance loss. The probable ultimate urban requirement was assumed to be the computed requirement for applied water plus an additional 10 per cent for irrecoverable conveyance losses. Since the entire urban development in the San Francisco Bay Area was assumed to be sewered under ultimate conditions of development, it was considered improbable that sizeable contributions to ground water would occur from this source.

Ultimate water requirements in other water service areas were estimated on the basis of expected utilization of such areas for recreational and other purposes. The water to meet this requirement is expected to be developed from local supplies, and to be utilized principally for domestic purposes.

No consideration was given to reclamation and re-use of sewage which would otherwise be discharged to the ocean. Large quantities of water in the San Francisco Bay Area could be salvaged in this manner, and experimental projects to determine the feasibility of reclamation of sewage are presently being conducted in southern California. Sufficient data are not presently available to evaluate the effect of such sewage reclamation on requirements for supplemental water supplies. Exploitation of this potential source of water supply is considered as development of new water for purposes of this bulletin.

In several hydrographic units of the San Francisco Bay Area the present application of water on irrigated lands is somewhat less than the optimum amount required for consumptive use for agriculture. This condition is caused by the low transmissibility characteristics of presently developed ground water resources, and the consequent inability to produce the required amounts of water from existing wells. It is believed that crop production in these areas has been adversely affected thereby.

Table 47 presents estimated present and probable ultimate water requirements for each hydrographic unit of the San Francisco Bay Area.

Estimates of ultimate water requirements, expressed as a function of the relative proportions of the habitable area which may be devoted to urban and suburban and agricultural development, are presented in Table 48. In deriving the quantities expressed in this table, the present irrigated crop pattern was gradually modified so that truck crops, flowers, and dairies constituted increasing percentages of the lands available for irrigated culture.

Table 48 demonstrates that a relatively small effect on the ultimate water requirement results from a comparatively large variation in the degree of urbanization. The change in seasonal water requirement for and increase in urbanization from 50 to 100 per cent amounts to only about 10 per cent of the average requirement for the area. The assumption of practically complete urbanization under conditions of ultimate development provides a conservative basis for future planning of projects to provide for necessary supplemental water requirements.

Ultimate urban and suburban water requirements in the San Francisco Bay Area were also independently estimated on the basis of forecast ultimate population. This procedure involved determination of the areas ultimately susceptible of urban and suburban development, the ultimate population densities in these areas, and the ultimate per capita water requirement.

The general method of estimating ultimate population was outlined in Chapter II, "Methods and Procedures." In most of the San Francisco Bay Area it was assumed that future residential development would take place in accordance with patterns indicated by recent building trends, so that over-all densities would be somewhat less than the existing densities in the present fully developed areas. An exception to such a pattern was forecast for the northern portion of Contra Costa County, where the expected concentration of very heavy industry was assumed to require the future development of housing with the present heavier density characteristics.

TABLE 47

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER, SAN FRANCISCO BAY AREA

(In acre-feet)

Hydrographic unit		Present requirements				Ultimate requirements without reclamation of tidelands					Ultimate requirements with reclamation of tidelands				
Reference number	Name	Irrigated lands	Urban and suburban areas	Unclassified areas	Approximate total	Irrigated lands	Farm lots	Urban and suburban areas	Other water service areas	Approximate total	Irrigated lands	Farm lots	Urban and suburban areas	Other water service areas	Approximate total
1	Marin-Sonoma	6,200	16,500	4,200	26,900	12,600	400	530,000	400	543,000	12,600	400	607,000	400	620,000
2	Napa Valley	6,300	13,600	5,200	25,100	8,300	200	278,000	100	287,000	8,300	200	321,000	300	330,000
3	Solano	23,600	2,200	3,600	29,400	57,300	1,400	295,000	100	354,000	57,300	1,400	320,000	0	379,000
4	Contra Costa	19,400	93,700	2,700	116,000	0	0	458,000	400	458,000	0	0	494,000	400	494,000
5	Livermore Valley	11,900	3,900	2,300	18,100	14,300	400	200,000	200	215,000	14,300	400	200,000	200	215,000
6	Alameda-Bayside	61,600	94,400	5,700	162,000	1,700	100	338,000	400	340,000	1,700	100	487,000	300	489,000
7	Santa Clara Valley	157,000	43,500	5,200	206,000	2,400	200	517,000	700	520,000	2,400	200	523,000	800	526,000
8	San Mateo-Bayside	4,000	31,600	500	36,100	0	0	216,000	100	216,000	0	0	264,000	100	264,000
9	San Mateo-Coastal	11,000	3,000	1,200	15,200	1,700	100	64,000	100	65,900	1,700	100	64,000	100	65,900
10	San Francisco	0	85,400	5,000	90,400	0	0	125,000	0	125,000	0	0	129,000	0	129,000
	APPROXIMATE TOTALS	301,000	388,000	35,600	725,000	98,300	2,800	3,021,000	2,500	3,124,000	98,300	2,800	3,409,000	2,600	3,512,000

TABLE 48

ESTIMATED ULTIMATE MEAN SEASONAL WATER REQUIREMENTS AS A FUNCTION OF TYPE OF LAND USE, SAN FRANCISCO BAY AREA

Urban and suburban areas, in percent	Irrigated lands, in percent	Ultimate consumptive requirements for water, in acre-feet	
		Without reclamation of tidelands	With reclamation of tidelands
50	50	2,870,000	3,230,000
60	40	2,930,000	3,310,000
70	30	2,970,000	3,340,000
80	20	2,990,000	3,350,000
85	15	3,000,000	3,380,000
90	10	3,060,000	3,420,000
100	0	3,180,000	3,560,000

It was estimated that the ultimate population for the San Francisco Bay Area will be about 13,450,000. Based on available data on present use of water in portions of the area, it was indicated that the ultimate per capita water requirement will vary from about 150 gallons to about 236 gallons per day, including an allowance of 10 per cent for distribution losses.

It was assumed that prospective reclamation of tidelands had not occurred and, on this basis, the ultimate urban and suburban seasonal water requirement was estimated to be about 2,600,000 acre-feet. This may be compared with the estimated value of about 3,020,000 acre-feet, as presented in Table 47, based upon the land use type of determination. The estimates of ultimate population, per capita use of water, and urban water requirement are presented in Table 49 for the portions of counties included within the San Francisco Bay Area.

TABLE 49

ESTIMATED ULTIMATE POPULATION, PER CAPITA USE OF WATER, AND URBAN WATER REQUIREMENT, SAN FRANCISCO BAY AREA

County	Ultimate population	Ultimate water requirements	
		Gallons per capita per day	Acre-feet per year
Alameda	2,430,000	151	411,000
Contra Costa	1,970,000	236	521,000
Marin	545,000	156	95,000
Napa	1,100,000	172	212,000
San Francisco	845,000	106	100,000
San Mateo	1,205,000	163	220,000
Santa Clara	2,180,000	172	420,000
Santa Cruz	0	0	0
Solano	1,980,000	175	388,000
Sonoma	1,195,000	169	226,000
TOTALS	13,450,000		2,593,000

Supplemental Requirements

Supplemental water requirement, as the term is used in this bulletin, refers to the quantity of water, in addition to safe yield of the present water supply development, which must be made available to satisfy fully the present or probable ultimate water requirement. The present supplemental requirement represents the difference between the present water requirement and the sum of presently developed safe yield of local supplies and present import of water. The difference between estimated present and probable ultimate water requirements for each hydrographic unit plus the present supplemental requirement was taken as the measure of the probable ultimate supplemental water requirement.

As has been shown, water requirements in the San Francisco Bay Area under conditions of ultimate development will vary with the assumptions of ultimate land use pattern. For the purpose of determining the ultimate supplemental water requirement, the consumptive water requirement with 95 per cent urbanization and 5 per cent irrigated agriculture in the ultimate water service area was assumed.

Safe Yield of Local and Imported Water Supplies With Present Development. In connection with studies to determine values of presently developed safe seasonal local yield, use was made of data appearing in recent publications of the State Water Resources Board, the Division of Water Resources, and other organizations. Use was also made of unpublished data compiled in conjunction with the investigations currently being conducted by the Division of Water Resources. Values of safe yield presented in this bulletin in many instances must be considered as approximations and only indicative of the general order of magnitude. In those areas where detailed data were not available and where water shortages are not presently apparent, safe yield of the present water supply development was assumed to be equal to the estimated present water requirement.

The Division of Water Resources is presently conducting a special investigation for the State Water Resources Board in the Santa Clara Valley, the results of which will be published as Bulletin No. 7, "Santa Clara Valley Investigation." This investigation covers the ground water basin underlying the north Santa Clara Valley, which includes a substantial portion of the Santa Clara Valley Hydrographic Unit. It has been determined that of 165,000 acres in the ground water basin, 86,000 acres are located in a free ground water zone and 79,000 acres in a pressure zone. It was estimated that in 1949 a mean seasonal deficiency of about 20,000 acre-feet existed in the pressure zone and 17,000 acre-feet in the forebay zone. Subsequently, the Santa Clara Valley Water Conservation District completed Anderson and Lexington Reservoirs and numerous conduits designed to conserve and convey water to the forebay zone for recharge to ground water storage through percolation. Operation of these works indicates that the waters conserved are more than sufficient to meet the estimated total 1949 mean seasonal deficiencies of about 37,000 acre-feet. However, recent experience indicates that while depths to ground water have decreased in the forebay zone there has not been a corresponding decrease of pumping lift in the pressure zone. The result is that a deficiency in ground water supplies exists in the pressure zone, and will continue as long as the amount pumped exceeds the safe yield of the aquifers supplying this zone.

The present works for importation of water supplies to the San Francisco Bay Area consist of the Mokelumne Aqueduct of the East Bay Municipal Utility District, the Hetch Hetchy Aqueduct of the City of San Francisco, the Contra Costa Canal, constructed by the United States Bureau of Reclamation and serving the Contra Costa County Water District, and the Cache Slough Aqueduct of the City of Vallejo.

Estimates of presently developed safe seasonal yield of local and imported water supplies available to hydrographic units of the San Francisco Bay Area are presented in Table 50.

TABLE 50

ESTIMATED PRESENTLY DEVELOPED SAFE SEASONAL YIELD OF LOCAL AND IMPORTED WATER SUPPLIES, SAN FRANCISCO BAY AREA

(In acre-feet)

Hydrographic unit		Safe yield of presently constructed works
Reference number	Name	
1	Marin-Sonoma	24,000
2	Napa Valley	26,000
3	Solano	29,000
4	Contra Costa	219,000
5	Livermore Valley	4,000
6	Alameda-Bayside	181,000
7	Santa Clara Valley	197,000
8	San Mateo-Bayside	36,000
9	San Mateo-Coastal	15,000
10	San Francisco	184,000
	TOTAL	915,000

Allocation of Local and Imported Water Supplies. Under ultimate conditions of development, water supplies capable of importation to the San Francisco Bay Area by presently constructed works were assumed to be distributed to various hydrographic units in accordance with a schedule depending in part on the extent of reclamation of tidelands. The entire capacity of the Contra Costa Canal and a portion of that of the Mokelumne Aqueduct were applied against ultimate water demands of the Contra Costa Hydrographic Unit. The remaining water imported through the Mokelumne Aqueduct was applied to the Alameda-Bayside Hydrographic Unit. The safe yield of presently constructed works of the City of San Francisco not required to satisfy the ultimate requirements of the city was apportioned to San Mateo and Santa Clara Counties, with a small amount to Alameda County.

The allocation of such local and imported water supplies to the hydrographic units of the San Francisco Bay Area is presented in Table 51.

Supplemental Water Requirements. Present and probable ultimate supplemental water requirements in the San Francisco Bay Area generally were de-

TABLE 51

PROBABLE ULTIMATE ALLOCATION OF PRESENTLY AVAILABLE LOCAL AND IMPORTED WATER SUPPLIES, SAN FRANCISCO BAY AREA

(In acre-feet)

Hydrographic unit		Allocation without reclamation of tidelands	Allocation with reclamation of tidelands
Reference number	Name		
1	Marin-Sonoma	24,000	24,000
2	Napa Valley	26,000	26,000
3	Solano	29,000	29,000
4	Contra Costa	219,000	219,000
5	Livermore Valley	4,000	4,000
6	Alameda-Bayside	181,000	185,000
7	Santa Clara Valley	222,000	217,000
8	San Mateo-Bayside	67,000	66,000
9	San Mateo-Coastal	18,000	16,000
10	San Francisco	125,000	129,000
	TOTALS	915,000	915,000

TABLE 52

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS, SAN FRANCISCO BAY AREA

(In acre-feet)

Hydrographic unit		Present	Probable ultimate	
Reference number	Name		Without reclamation of tidelands	With reclamation of tidelands
1	Marin-Sonoma	3,000	519,000	596,000
2	Napa Valley	0	261,000	304,000
3	Solano	0	325,000	350,000
4	Contra Costa	0	239,000	275,000
5	Livermore Valley	14,000	211,000	211,000
6	Alameda-Bayside	15,000	159,000	304,000
7	Santa Clara Valley	0	298,000	309,000
8	San Mateo-Bayside	0	149,000	198,000
9	San Mateo-Coastal	0	47,900	49,900
10	San Francisco	0	0	0
	APPROXIMATE TOTALS	32,000	2,209,000	2,597,000

termined as the difference between water requirements, as presented in Table 47, and the sum of presently developed safe local yield and present import. The resultant estimates are presented in Table 52.

A present supplemental water requirement of 15,000 acre-feet exists in the southerly coastal portion of the Alameda-Bayside Hydrographic Unit, due to the lack of transmission and distribution facilities to serve that area. Inasmuch as the total presently developed safe yield of local and imported supplies is in excess of present requirements in the unit as a whole, the present supplemental requirement is not a factor in the estimate of ultimate water requirements in the Alameda-Bayside Hydrographic Unit.

CHAPTER V

CENTRAL COASTAL AREA

The Central Coastal Area lies along the Pacific Ocean between latitudes 34.5° and 37° N., and consists of those lands westerly from the drainage divide of the coastal ranges, a series of mountains paralleling the shore line in a general northwest to southeast direction. The area is designated Area 3 on Plate 8, and includes the Counties of Santa Cruz, Monterey, San Luis Obispo, and Santa Barbara, as well as the southern portion of Santa Clara County, the western portion of San Benito County, and small portions of Kern, Ventura, and San Mateo Counties. Among the principal incorporated cities are Hollister, Santa Cruz, Watsonville, Salinas, Monterey, Paso Robles, San Luis Obispo, Santa Maria, and Santa Barbara.

In order to facilitate the present studies, the Central Coastal Area was subdivided into 12 hydrographic units, the boundaries of which generally lie on the watershed divides of the principal streams, as shown on Plate 8. However, two of the stream basins, those of the Salinas and Pajaro Rivers, were each divided into two hydrographic units, an upper and a lower basin. Table 53 lists the 12 hydrographic units and their areas, and Table 54 presents the areas of the portion of each county included within the Central Coastal Area.

The climate of the Central Coastal Area is characterized by light precipitation, relatively mild temperatures, summer fogs along the coast, and an abundance of sunshine in the interior valleys throughout the greater part of the year. The Santa Cruz Mountains at the northern end of the area receive the greatest rainfall. The mean seasonal depth of precipitation at Ben Lomond, at an elevation of 500 feet in these mountains, is approximately 50 inches, while at Santa Cruz nearby on the coast it is a little over 28 inches. Throughout the floors of most valleys, precipitation is considerably lighter, averaging less than 15 inches per season. Along the coast of Santa Barbara County a greater quantity of rain falls, the seasonal mean depth being about 18.5 inches at Santa Barbara. Precipitation is extremely variable from year to year. At Salinas, where an unbroken record has been maintained since 1872 and the average seasonal depth of rainfall is 13.75 inches, the maximum quantity recorded in one season was 27.59 inches and the minimum was only 4.74 inches. Furthermore, over 90 per cent of rainfall in a typical year occurs during the six months from November through April, and only infrequent, scattered showers occur during summer and fall.

TABLE 53

AREAS OF HYDROGRAPHIC UNITS, CENTRAL COASTAL AREA

Hydrographic unit: Reference number	Hydrographic unit: Name	Acres
1	Santa Cruz	251,000
2	San Benito	782,000
3	Pajaro	69,900
4	Upper Salinas	2,483,000
5	Lower Salinas	376,000
6	Carmel	182,000
7	Monterey Coast	343,000
8	San Luis Obispo	319,000
9	Carrizo Plains	273,000
10	Santa Maria	1,195,000
11	Santa Ynez	714,000
12	Santa Barbara	233,000
	APPROXIMATE TOTAL	7,221,000

TABLE 54

AREAS OF COUNTIES WITHIN BOUNDARIES OF CENTRAL COASTAL AREA

County	Acres
Kern	6,400
Monterey	2,129,000
San Benito	689,000
San Luis Obispo	2,025,000
San Mateo	24,300
Santa Barbara	1,625,000
Santa Clara	225,000
Santa Cruz	279,000
Ventura	218,000
APPROXIMATE TOTAL	7,221,000

The estimated mean seasonal natural runoff of streams in the Central Coastal Area is about 2,448,000 acre-feet, or about 3.4 per cent of that for the entire State. Approximately one-half of the runoff is provided by the Salinas, Pajaro, Santa Maria, and Santa Ynez Rivers, and the remainder by a multitude of small creeks and channels that drain directly into the Pacific Ocean. The estimated mean seasonal natural runoff of the Salinas River, largest of the streams, is approximately 714,000 acre-feet, or about 29 per cent of the total runoff of the area. The occurrence of any substantial amount of precipitation has a direct and immediate effect on the flow of streams. For the most part the streams are quite short, and the characteristic runoff after a rainstorm is of high intensity but short duration. Following the pattern of precipitation within the season, stream flow is greatly reduced after about the first of May in an average year, and many

The Salinas Valley

Courtesy Salinas Chamber of Commerce

Harvesting Lettuce in Central Coastal Area

Courtesy Salinas Chamber of Commerce

streams are completely dry during the late summer. The Arroyo Seco, a principal tributary of the Salinas River, is fairly representative of other streams of the area, and records show that approximately 80 per cent of its runoff occurs during the months of January, February, March, and April.

As shown on Plate 4, a total of 19 valley fill areas, which may or may not contain usable ground water, has been identified in the Central Coastal Area. In 11 of these areas, ground water has been developed and utilized in varying degrees for irrigation purposes. The principal ground water basins in size and importance as related to use are those underlying irrigated lands of the Salinas, San Benito, Pajaro, Santa Maria, Santa Ynez, and Cuyama Valleys. Most of the present regulation of the water resources of the Central Coastal Area is provided by natural storage in the ground water basins. Generally speaking, the aquifers are quite permeable and yield adequate flows to deep-well turbine pumps. Those ground water basins located adjacent to the coast have characteristic confining impervious strata that overlie the aquifers and extend inland from the ocean for several miles. Studies indicate that overdrafts now exist in a number of the basins. These overdrafts are generally localized, and result from the inability of the aquifers either to receive replenishment during wet periods sufficient to meet seasonal requirements for water, or to convey water to centers of pumping draft at rates sufficient to meet peak demands. In certain of the coastal basins, present extraction of water exceeds replenishment, and resultant intrusion of sea water into the confined aquifers is becoming a critical problem. Investigations indicate that three such ground water basins are presently being invaded, and that six more are areas of potential sea-water intrusion.

Growth of population in the Central Coastal Area during recent years has generally kept pace with the phenomenal growth in other portions of the State. The population of the area has increased from an estimated 242,000 in 1940 to 373,000 in 1950, or some 54 per cent. Nearly all urban centers have correspondingly grown in size and importance. Table 55 shows the increase in population of seven of the principal urban communities from 1940 to 1950. It may be noted that a substantial part of the recent increase in population has occurred in suburbs immediately outside of city limits.

Agriculture is the major economic activity of the Central Coastal Area. In the large valleys between ridges of the coastal ranges, and on the coastal plain wherever ground water supplies are available, lands have been extensively developed to irrigated agriculture. Since 1900 the area devoted to irrigation has increased from approximately 15,000 acres to about 338,000. Many of the smaller valleys and most of the foothill grass lands constitute an important stock-raising region. Certain of the irrigated localities have been developed to specialty crops, notably seed and nursery crops, and artichokes, brussels sprouts, lettuce, berries, and citrus.

Developments for providing water supplies were initiated by the first settlers in the Central Coastal Area. The mild winters, long, dry summers, and characteristic droughts sustained over several seasons made it necessary from the beginning to construct small diversion dams and ditches, and to dig shallow wells in order to provide a dependable water supply. The Spanish Padres, in the latter part of the eighteenth century, made the first use of irrigation water in the area. In order to irrigate fields surrounding in the Missions of Soledad, San Antonio, and Santa Barbara, small ditches were dug to divert the flow from adjacent streams. However, following the secularization of the California Missions in 1833, irrigation was largely abandoned for approximately 50 years. In the Eleventh Federal Census, the first to take irrigation into consideration, the following statements summarize the status of irrigation in 1890 for the counties indicated:

> "Santa Cruz—On the lower grounds near the coast a little irrigation is practiced, as in adjoining counties, water being applied during late summer to the gardens and trees. For this purpose there are a few small ditches, and in a number of instances water is pumped from wells or other sources of supply. In the vicinity of Watsonville there are a number of flowing wells, mainly on the low ground

TABLE 55

POPULATION OF PRINCIPAL URBAN CENTERS, CENTRAL COASTAL AREA

City	1940			1950		
	Within city limits	In suburbs	Totals	Within city limits	In suburbs	Totals
Santa Barbara	35,000	2,600	37,600	44,900	4,400	49,300
Monterey-Pacific Grove-Carmel	19,200	3,900	23,100	30,200	14,200	44,400
Salinas	11,600	9,500	21,100	13,900	25,300	39,200
Santa Cruz	16,900	5,100	22,000	21,900	14,000	35,900
Santa Maria	8,500	1,900	10,400	10,400	6,200	16,600
San Luis Obispo	8,900	600	9,500	14,200	700	14,900
Watsonville	8,900	1,600	10,500	11,600	3,200	14,800

within a mile of the coast. The water from these wells is used to a very small extent for irrigation.

"San Benito—Fruit raising is profitably carried on, especially in the vicinity of San Juan, Hollister and other towns. Irrigation is little practiced, since nearly all products are successful without the artificial application of water. Along San Benito River, however, and other streams a number of small irrigating ditches have been dug, these being usually from one to two miles in length. Water from artesian wells is also used to a small extent for fruit trees and alfalfa.

"Monterey—In Salinas and the smaller valleys agriculture is carried on successfully without irrigation in spite of the fact that the annual rainfall is very small, averaging probably from 10 to 15 inches. The small amount of the annual precipitation is in part compensated by the relatively moist winds from the ocean. Most of the best agricultural land has been covered by land grants and is still held in large bodies, used principally for grazing. Irrigation, where practiced, is conducted on a small scale, the waters of springs and rivulets being utilized by individuals having land conveniently situated.

"The canal of the San Bernardo and Salinas Valley Canal and Irrigation Company takes water from Salinas River in the southern part of the county, not far from the town of Sargent. It is built on the east side of the river for a distance of six miles. The average width is ten feet, and the cost was $25,000. The canal, owned by a corporation, was begun in 1884 and first used in about 1888. The principal crop irrigated at present is alfalfa. The water supply is fairly good, although the river is dry at times, the water sinking in the bed of the stream.

"San Luis Obispo—Irrigation is not practiced, although the water supply of the county is large, and in the interior valley, especially, water could probably be applied to advantage during the summer months. Within the county there are reported to be a number of flowing wells, these being on the low lands near the mouth of Santa Maria River, and at localities where it is not necessary to irrigate.

"Santa Barbara—This county has a moist climate, and irrigation is confined mainly to watering orchards, vineyards, and gardens in the vicinity of the towns along the southern coast, especially during the latter part of the summer. The water supply is small, being derived from the streams flowing from the mountains bordering the coast. The greater part of the land is irrigated by means of pumps or engines, or by pipe lines laid from some spring or mountain stream. North of the Santa Inez Mountains, which stretch along the southern coast, are several broad valleys in which agriculture is carried on successfully. It is probable that irrigation may be introduced to a small extent as development proceeds, as there are a number of streams whose waters can be utilized at reasonable expense."

Irrigation development in the Central Coastal Area has passed through three phases in reaching the present state of high productivity. The first methods of irrigation were by small diversions from streams, rivulets, or springs, to lands conveniently situated. Secondly, pumps driven by steam engines were installed along the rivers, and water was pumped out onto the lands. The third phase was the beginning of the method which is now used by the majority of irrigators, that is, pumping directly from the ground water. Originally, large centrifugal pumps were installed in deep pits, and water was pumped to the surface for the irrigation of relatively large service areas, as though from surface streams. As motor-driven deep-well pumps came into general use, the large installations were abandoned, and individual wells and pumps serving local areas were provided in their stead.

Up to the present time, surface water storage developments in the Central Coastal Area have been constructed primarily to provide urban water supplies. The California Water and Telephone Company has two reservoirs on the Carmel River, San Clemente and Los Padres, which provide water for Pacific Grove, Monterey, and Carmel. The United States Bureau of Reclamation is constructing Cachuma Dam and Reservoir on the Santa Ynez River, which by a tunnel diversion through the Santa Ynez Mountains will deliver supplemental water to Santa Barbara and to nearby agricultural and suburban areas. Gibralter and Juncal Reservoirs on the Santa Ynez River conserve water which is diverted by tunnels through the Santa Ynez Mountains, to provide the City of Santa Barbara and the Montecito County Water District most of their present water supplies. Salinas Dam on the headwaters of the Salinas River serves water to San Luis Obispo and to Camp San Luis Obispo, an adjoining military establishment. A conservation reservoir at the Winchester Ranch site on the Nacimiento River is proposed for construction by the Monterey County Flood Control and Water Conservation District, and a bond issue for construction has been approved by voters of the county.

Remaining communities of the area, through municipal or privately-owned water systems, utilize ground water or direct stream diversion in serving their municipal needs. The only water storage development solely for irrigation purposes is the North Fork Dam and Reservoir on Pacheco Creek, which is so operated as to retain winter runoff for later release to supplement the ground water supply in the Gilroy-Hollister area. A compilation of the principal

Courtesy State Division of Highways

The Central Coast

water service agencies in the Central Coastal Area is included in Appendix B, together with the number of domestic services and irrigated areas served by each agency.

The mild, equable climate and outstanding scenic attractions of the Central Coastal Area have resulted in the establishment of many resorts and an important tourist trade. This development is largely centered in the Santa Cruz Mountains and along the coast in and adjacent to Santa Cruz, Monterey, and Carmel, and in the vicinity of Santa Barbara. Aside from this resort development and tourist trade, most industry is closely allied with agriculture, and consists principally of sugar refineries, refrigeration plants, canneries, and other food processing and packing establishments, and steam-electric power generating plants. However, several oil fields have been developed in the area, the most important of which are in the vicinity of Santa Maria and the Cuyama Valley. Furthermore, there is some lumbering in the Santa Cruz Mountains, and a commercial and sport fishing industry operates out of Monterey Bay.

Six major and several minor military establishments have been of varying importance to the economy of the Central Coastal Area. The principal present posts are Fort Ord, the Presidio of Monterey, and Camp Hunter Liggett. The California Department of Corrections is operating the hospital area at Camp San Luis Obispo, and the United State Department of Defense is maintaining the remainder of the reservation in a caretaking status. Camp Roberts and Camp Cooke were operated as training establishments during World War II. Both camps were subsequently placed in an inactive status by the Department of Defense and are retained in such status at the present time. Deposits of oil in the Camp Cooke area are under development.

The trend of agriculture in the Central Coastal Area during the past few years has been toward more intensive development of the highly productive soils that overlie ground water basins. In the truck crop producing regions, two and three crops are frequently produced annually. However, of the relatively large area of irrigable land not overlying ground water readily obtainable by pumping from wells, only a very small portion is irrigated at the present time. It is anticipated that ultimately most of such land will be developed for irrigated agriculture. Most urban centers in the area are still comparatively small, with low population densities. While some increase in population density has occurred with growth, the recent trend has been toward construction of subdivisions on lands immediately surrounding the existing towns. In some cases this has encroached upon the area devoted to agriculture.

While mining is not a major factor in the economy of the area as a whole, it is extensively developed in some localities. The deposits of diatomite near Lompoc provide more than 90 percent of the total quantity used in the United States each year, for the manufacture of commercial abrasives, metal polishes, dental powder, and other purposes. Silica sand is produced in the Monterey area, and table salt and magnesium are reclaimed from ocean water. Sand and gravel, cement, and miscellaneous stones are produced in small quantities throughout the Central Coastal Area.

Portions of the Central Coastal Area are now utilized predominantly for recreational purposes, and it is anticipated that the trend toward this type of development will continue as the population of the State increases. Desirable coastal recreational areas in California are limited, and it is believed that nearly all suitable locations will ultimately be devoted to this type of development. Inland climates are not as desirable for year-round recreational living as those near the coast, but it is believed that ultimately the interior valleys may support a substantial light industry.

In summary, it should be emphasized that water is employed in the Central Coastal Area primarily for the production of agricultural crops, and to a much smaller extent for municipal purposes including domestic and industrial. It is expected that water for irrigation will remain predominant among the many uses of water into the indefinite future. Insofar as is known, no water is now utilized in the area for the generation of hydroelectric power nor for navigation purposes, nor is it foreseen that there will ever be appreciable requirements of such nature. Flood control structures, the operation of which involves rapid regulated disposal of flood waters, have not as yet been constructed in the Central Coastal Area, although several are in the planning stage, and it is probable that more will be planned and constructed in the future. The present use of water for recreation is limited to water consumed for domestic purposes in resort and recreational areas, and to water naturally utilized in supporting stream flow in such areas. With anticipated growth of the State and increase in the demand for recreational opportunity, it is probable that additional water supplies will be developed and utilized for the preservation and propagation of fish and wildlife, particularly in the streams of Santa Cruz County.

There follows a presentation of available data and estimates pertinent to the nature and extent of water requirements in the Central Coastal Area, both at the present time and under conditions of probable ultimate development.

PRESENT WATER SERVICE AREAS

As a necessary step in estimating the amount of the water requirement in the Central Coastal Area, determinations were made of the location, nature, and extent of present irrigated and urban and suburban water service areas. Remaining lands were not classified in detail with regard to their relatively minor miscellaneous types of water service, although such water service was given consideration in estimating the present water requirement.

Irrigated Lands

It was determined that under present conditions of development in the Central Coastal Area, about 338,000 acres are irrigated in a given year, on the average. This constitutes approximately five per cent of the land irrigated throughout California.

Irrigated truck and field crops are dominant in acreage and value in the area. Cabbage, brussels sprouts, broccoli, and artichokes are produced along the cool coastal strip from Santa Cruz to Santa Maria, while just inland are grown lettuce, cabbage, beans, sugar beets, flowers, and nursery crops. In the inland valley in the vicinity of Hollister, truck and field crops dominate, but in addition there are extensive areas of deciduous fruit orchards and walnuts. Along the coast in Santa Barbara County the irrigated lands produce walnuts, lemons, and truck crops. In the upper drainage basins of the San Benito, Salinas, Cuyama, and Santa Ynez Rivers, small areas are devoted to irrigated pasture and alfalfa that supplement the native range land used for spring pasture.

In the Salinas Valley approximately two-thirds of the lands devoted to lettuce produce two crops during the summer, and the remaining third a single crop. Cover-cropping is the general practice for lettuce land during the winter. In the Pajaro Valley about half of the lettuce acreage produces two crops each year. Double-cropping is generally practiced on land devoted to beans, peas, spinach, onions, and other truck crops with a short growing season.

The field surveys upon which determinations of irrigated acreage in the Central Coastal Area were based were accomplished during the period from 1947 through 1950, by several agencies and with varying standards and degrees of accuracy. Information regarding the dates of field mapping and sources of data is contained in Appendix E. Based on the available survey data, the irrigated lands were classified into various crop groups, with a view to segregating those of similar water use. Detailed segregation of individual truck and nursery crops was found to be impracticable. In some localities, information on acreages of a few of the dominant truck crops was available, but since the segregation was not consistent throughout the entire area these acreages were regrouped simply as truck crops. In general, the acreages of sugar beets were separately determined. Throughout Santa Barbara County, however, such detailed information was not available, and all field crops including sugar beets were classified in one group. A list of the various crop groups into which irrigated lands of the Central Coastal Area were classified follows:

Alfalfa	Hay, seed, and pasture
Pasture	Grasses and legumes, other than alfalfa, used for livestock forage
Orchard	Deciduous fruit, nuts, and olives
Citrus	Oranges, lemons, grapefruit, and avocados
Vineyard	All varieties of grapes
Truck crops	Intensively cultivated fresh vegetables, including tomatoes, lettuce, artichokes, brussels sprouts, cabbages, carrots, peppers, broccoli, flower seed, and nursery crops
Sugar beets	
Miscellaneous field crops	Dry beans, milo, corn, hops, hay, grain, etc., and unsegregated sugar beets in Santa Barbara County

It was estimated that approximately 5,900 acres in the Central Coastal Area are occupied by farm lots at the present time. These consist of farm buildings and areas immediately surrounding them that receive water service.

Summaries of presently irrigated acreages within the Central Coastal Area by the various crop groups are presented in Tables 56 and 57. Table 56 lists the acreages by hydrographic units, and Table 57 by counties.

Urban and Suburban Water Service Areas

It was determined that under present conditions of development in the Central Coastal Area approximately 48,000 acres are devoted to urban and suburban types of land use. For the most part, the business, commercial, and industrial establishments and surrounding homes included in this areal classification receive a municipal type of water supply. Areas of urban and suburban water service within each hydrographic unit of the Central Coastal Area are listed in Table 58, and within each county in Table 59. It should be noted that the areas shown are gross acreages, as they include streets and intermingled undeveloped lands that are a part of the urban type of community.

Unclassified Areas

Remaining lands in the Central Coastal Area, other than those that are irrigated or urban and suburban in character, were not classified in detail as regards present water service. Of a total of about 6,820,000 acres of such remaining lands, less than 13,000 acres actually receive water service at the present time. These relatively minor service areas consist of scat-

TABLE 56

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, CENTRAL COASTAL AREA

(In acres)

Hydrographic unit		Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Sugar beets	Miscellaneous field crops	Approximate net irrigated area	Farm lots	Included nonwater sevice area	Approximate gross area
Reference number	Name												
1	Santa Cruz	0	200	0	0	0	4,400	0	300	4,900	100	200	5,200
2	San Benito	2,900	5,100	28,700	0	3,000	11,700	8,300	10,500	70,200	1,400	2,200	73,800
3	Pajaro	200	700	3,200	0	0	11,700	1,500	800	18,100	400	600	19,100
4	Upper Salinas	1,300	1,600	100	0	0	0	0	700	3,700	0	100	3,800
5	Lower Salinas	15,900	9,200	2,600	0	0	52,600	16,500	45,100	142,000	2,000	4,500	148,000
6	Carmel	100	100	300	0	0	600	0	100	1,200	0	100	1,300
7	Monterey Coast	0	0	0	0	0	0	0	0	0	0	0	0
8	San Luis Obispo	300	400	400	0	0	3,300	0	500	4,900	100	200	5,200
9	Carrizo Plains	0	0	0	0	0	0	0	0	0	0	0	0
10	Santa Maria	5,100	2,700	200	0	0	33,600	0	12,200	53,800	1,000	1,800	56,600
11	Santa Ynez	4,800	2,600	1,000	0	0	10,200	0	3,500	22,100	400	600	23,100
12	Santa Barbara	300	1,900	1,800	10,300	0	1,200	0	2,200	17,700	500	500	18,700
	APPROXIMATE TOTALS	30,900	24,500	38,300	10,300	3,000	129,000	26,300	75,900	338,000	5,900	10,800	355,000

TABLE 57

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN COUNTIES, CENTRAL COASTAL AREA

(In acres)

County	Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Sugar beets	Miscellaneous field crops	Approximate net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
Monterey	17,100	11,000	4,000	0	0	57,400	16,500	46,300	152,000	2,300	4,800	159,000
San Benito	1,800	3,600	11,200	0	700	6,100	6,600	9,800	39,800	800	1,100	41,700
San Luis Obispo	2,400	1,500	600	0	0	13,100	0	7,700	25,300	300	900	26,500
San Mateo	0	0	0	0	0	1,200	0	300	1,500	0	100	1,600
Santa Barbara	8,400	6,200	2,900	10,300	0	35,200	0	11,100	74,100	1,700	2,100	77,900
Santa Clara	1,100	1,600	17,600	0	2,300	5,600	1,700	700	30,600	600	1,100	32,300
Santa Cruz	100	600	2,000	0	0	10,700	1,500	0	14,900	200	700	15,800
APPROXIMATE TOTALS	30,900	24,500	38,300	10,300	3,000	129,000	26,300	75,900	338,000	5,900	10,800	355,000

tered developed portions of national forests and monuments, public beaches and parks, private recreational areas, military reservations, etc.

The Los Padres National Forest, extending along the coast in Monterey County and including the San Rafael and Santa Ynez Mountains, is the largest national reservation in the Central Coastal Area. It includes approximately 1,400,000 acres, much of which is rough in topography and covered by native brush, grass, and scattered trees. Some 2,900 acres of the national forest lands are presently irrigated, which acreage is included in the values listed in Tables 56 and 57. Irrigation is practiced in several of the smaller mountain valleys in the national forest, but the major development is on the coastal plain along the south edge of the Santa Ynez Mountains, where it is estimated that about 2,700 acres are irrigated. Within the national forest there are also administration buildings, public camps, trailer parks, and other accommodations for tourists, but the actual water service area involved in these features is small.

The Division of Beaches and Parks of the State Department of Natural Resources at present administers 29 public beaches and parks throughout the Central Coastal Area. These recreational areas aggregate nearly 15,000 acres, but water service primarily consists of domestic supplies for the permanent buildings and surrounding grounds, and summer water supplies for camp grounds and picnic areas. Pinnacles National Monument in San Benito County, under jurisdiction of the National Park Service, includes some 12,800 acres of land, with water service similar to that of the state beaches and parks.

Private recreational areas within the Central Coastal Area are largely confined to the Santa Cruz Mountains. Approximately 6,900 acres are included in this category.

The area of military establishments within the Central Coastal Area totals about 425,000 acres. In general, the reservations consist of the base installation, including quarters and administration buildings, and large areas of undeveloped land utilized for training purposes. The boundaries of certain of the reservations extend into the national forest. The acreage of lands presently irrigated within military reservations is included in the values listed in Tables 56 and 57.

Summary

Table 58 comprises a summary of present water service areas within hydrographic units of the Central Coastal Area. A similar summary for counties of the area is presented in Table 59.

TABLE 58

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS, CENTRAL COASTAL AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands	Urban and suburban areas	Approximate total
1	Santa Cruz	5,200	8,100	13,300
2	San Benito	73,800	2,100	75,900
3	Pajaro	19,100	1,900	21,000
4	Upper Salinas	3,800	1,700	5,500
5	Lower Salinas	148,000	5,500	154,000
6	Carmel	1,300	16,100	17,400
7	Monterey Coast	0	0	0
8	San Luis Obispo	5,200	4,000	9,200
9	Carrizo Plains	0	0	0
10	Santa Maria	56,600	1,600	58,200
11	Santa Ynez	23,100	800	23,900
12	Santa Barbara	18,700	6,600	25,300
	Subtotals	355,000	48,400	404,000
	Unclassified areas receiving water service			12,200
	APPROXIMATE TOTAL			416,000

TABLE 59

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN COUNTIES, CENTRAL COASTAL AREA

(In acres)

County	Irrigated lands	Urban and suburban areas	Approximate total
Kern	0	0	0
Monterey	159,000	23,300	183,000
San Benito	41,700	2,100	43,800
San Luis Obispo	26,500	4,800	31,300
San Mateo	1,600	0	1,600
Santa Barbara	77,900	8,200	86,100
Santa Clara	32,300	0	32,300
Santa Cruz	15,800	10,000	25,800
Subtotals	355,000	48,400	404,000
Unclassified areas receiving water service			12,200
APPROXIMATE TOTAL			416,000

PROBABLE ULTIMATE WATER SERVICE AREAS

To aid in estimating the amount of water that ultimately will be utilized in the Central Coastal Area, projections were first made to determine the probable ultimate irrigated and urban and suburban water service areas. It was assumed that the remaining lands, for convenience referred to as "other water service areas," ultimately will be served with water commensurate with their needs.

Irrigated Lands

Based on data from land classification surveys, it was estimated that a gross area of approximately 1,368,000 acres in the Central Coastal Area is suitable for irrigated agriculture. Excepting farm lots and certain lands within the gross area that experience indicates will never be served with water, such as lands occupied by roads, railroads, etc., it was estimated that under ultimate conditions of development a net area of approximately 1,166,000 acres will actually be irrigated. Table 60 presents these esti-

TABLE 60

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, CENTRAL COASTAL AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
1	Santa Cruz	13,100	200	3,400	9,500
2	San Benito	168,000	3,000	18,800	146,000
3	Pajaro	36,500	500	9,100	26,900
4	Upper Salinas	352,000	3,800	52,500	296,000
5	Lower Salinas	268,000	4,100	28,100	236,000
6	Carmel	7,400	100	800	6,500
7	Monterey Coast	15,400	200	2,100	13,100
8	San Luis Obispo	73,500	1,000	10,000	62,500
9	Carrizo Plains	86,500	1,200	10,900	74,400
10	Santa Maria	181,000	2,700	24,500	154,000
11	Santa Ynez	121,000	1,800	17,500	102,000
12	Santa Barbara	45,800	900	5,300	39,600
	APPROXIMATE TOTALS	1,368,000	19,500	183,000	1,166,000

TABLE 61

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN COUNTIES, CENTRAL COASTAL AREA

(In acres)

County	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
Kern	800	0	100	700
Monterey	420,000	6,200	56,900	357,000
San Benito	126,000	1,900	15,500	109,000
San Luis Obispo	438,000	5,700	57,500	375,000
San Mateo	5,500	100	1,700	3,700
Santa Barbara	286,000	4,000	39,900	242,000
Santa Clara	55,500	800	7,400	47,300
Santa Cruz	35,700	800	3,900	31,000
Ventura	400	0	100	300
APPROXIMATE TOTALS	1,368,000	19,500	183,000	1,166,000

TABLE 62

PROBABLE ULTIMATE PATTERN OF IRRIGATED CROPS, CENTRAL COASTAL AREA

(In acres)

Hydrographic unit		Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Sugar beets	Miscellaneous field crops	Hay and grain	Approximate total
Reference number	Name										
1	Santa Cruz	0	1,500	0	0	0	4,000	0	2,000	2,000	9,500
2	San Benito	8,000	6,800	48,500	0	10,000	28,600	18,600	9,300	16,300	146,000
3	Pajaro	2,000	1,500	4,500	0	0	15,000	0	3,900	0	26,900
4	Upper Salinas	5,000	77,400	10,000	0	27,000	2,500	0	95,100	78,700	296,000
5	Lower Salinas	30,000	6,100	10,000	0	0	93,200	35,000	38,000	23,900	236,000
6	Carmel	1,000	2,000	2,000	0	0	1,500	0	0	0	6,500
7	Monterey Coast	0	5,000	0	0	0	1,500	0	2,400	4,200	13,100
8	San Luis Obispo	200	23,800	3,100	0	1,700	1,800	0	11,400	20,500	62,500
9	Carrizo Plains	0	19,100	8,100	0	0	2,100	0	14,000	31,100	74,400
10	Santa Maria	15,300	13,600	8,000	0	2,500	54,300	4,800	15,000	40,800	154,000
11	Santa Ynez	11,100	5,100	12,600	8,000	0	12,300	10,600	10,300	31,700	102,000
12	Santa Barbara	3,000	1,900	6,200	24,600	0	2,100	0	1,000	800	39,600
	APPROXIMATE TOTALS	75,600	164,000	113,000	32,600	41,200	219,000	69,000	202,000	250,000	1,166,000

mates for hydrographic units of the Central Coastal Area, and Table 61 for the various counties.

The probable ultimate crop pattern for irrigated lands of the Central Coastal Area is presented in Table 62. The crop grouping parallels that used in the case of present development, except for the added group titled "Hay and grain." This group was of minor importance and not segregated in the case of the present crop pattern, but is expected to be of greater significance in the future.

Urban and Suburban Water Service Areas

While it is expected that urban and suburban growth in the Central Coastal Area generally will be associated with further development of agriculture, the favorable climate and scenic attractions will probably influence growth of certain population centers. Population increase may also be brought about by expansion of present and new industries. It was estimated that under ultimate conditions of development the urban and suburban water service areas will have increased to approximately 138,000 acres. Urban and suburban types of land use are expected to occupy the same localities as at present, but vacant lands will be filled and densities increased. In addition, it is probable that encroachment will occur on surrounding lands in an estimated amount of about 90,000 acres. For the purposes of the present studies no attempt was made to delineate the boundaries of such encroachment, nor to determine what proportion will be on irrigable lands. The estimate of probable ultimate urban and suburban water service areas is included in Table 64. It should be noted that the areas shown are gross acreages, including streets, vacancies, etc.

Other Water Service Areas

Remaining lands of the Central Coastal Area, not classified as irrigable or urban and suburban under conditions of ultimate development, aggregate about 5,715,000 acres, or 80 per cent of the area. As previously mentioned, it was assumed that ultimately these lands will be served with water in amounts sufficient for their needs. No attempt was made to segregate these "other water service areas" in detail in regard to the nature of their probable ultimate water service. However, as shown in Table 63 they were broken down for convenience in estimating water requirements into those portions inside and outside of national forests, monuments, and military reservations, and above and below an elevation of 3,000 feet. The lands classified as "other water service areas" include recreational developments, both public and private, military establishments, residential and industrial types of land use outside of urban communities, etc. Most of these lands are situated in rough mountainous terrain, much of which is presently unaccessible. It is expected that even under conditions of ultimate development this large portion will be only sparsely settled, and will have only very minor requirements for water service.

Summary

Table 64 comprises a summary of probable ultimate water service areas, segregated into irrigable lands, urban and suburban areas, and other water service areas.

UNIT VALUES OF WATER USE

Recent investigations of the water resources of Santa Clara, Santa Cruz, Monterey, and Santa Barbara Counties provided much of the data used in estimating unit values of water use in the Central Coastal Area. These data were modified by standard methods to provide complete coverage of the area.

Irrigation Water Use

In general, unit seasonal values of consumptive use of water on lands devoted to the various irrigated

TABLE 63

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, CENTRAL COASTAL AREA

(In acres)

Hydrographic unit		Inside national forests, monuments, and military reservations		Outside national forests, monuments, and military reservations		Approximate total
Reference number	Name	Above 3,000-foot elevation	Below 3,000-foot elevation	Above 3,000-foot elevation	Below 3,000-foot elevation	
1	Santa Cruz	0	0	0	191,000	191,000
2	San Benito	0	0	69,600	539,000	609,000
3	Pajaro	0	0	0	28,500	28,500
4	Upper Salinas	69,700	371,000	52,000	1,633,000	2,126,000
5	Lower Salinas	0	11,400	0	77,900	89,300
6	Carmel	17,800	18,800	8,100	113,000	158,000
7	Monterey Coast	31,700	103,000	1,600	191,000	327,000
8	San Luis Obispo	0	45,500	0	191,000	236,000
9	Carrizo Plains	0	0	32,700	153,000	186,000
10	Santa Maria	392,000	229,000	39,200	348,000	1,008,000
11	Santa Ynez	136,000	156,000	1,400	297,000	590,000
12	Santa Barbara	7,100	85,400	0	73,900	166,000
	APPROXIMATE TOTALS	654,000	1,020,000	205,000	3,836,000	5,715,000

TABLE 64

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS, CENTRAL COASTAL AREA

(In acres)

Hydrographic unit		Irrigable lands	Urban and suburban areas	Other water service areas	Approximate total
Reference number	Name				
1	Santa Cruz	13,100	46,500	191,000	251,000
2	San Benito	168,000	5,300	609,000	782,000
3	Pajaro	36,500	4,900	28,500	69,900
4	Upper Salinas	352,000	4,900	2,126,000	2,483,000
5	Lower Salinas	268,000	18,500	89,300	376,000
6	Carmel	7,400	16,100	158,000	182,000
7	Monterey Coast	15,400	200	327,000	343,000
8	San Luis Obispo	73,500	9,800	236,000	319,000
9	Carrizo Plains	86,500	800	186,000	273,000
10	Santa Maria	181,000	6,000	1,008,000	1,195,000
11	Santa Ynez	121,000	3,500	590,000	714,000
12	Santa Barbara	45,800	21,700	166,000	233,000
	APPROXIMATE TOTALS	1,368,000	138,000	5,715,000	7,221,000

crops were computed by the methods outlined in Chapter II. However, as was pointed out in the prior discussion of irrigated lands, it is the practice in some localities to raise two or three crops on the same land in a given year. To account for this multiple land and water use, available results of actual field plot studies of application and use of water for irrigation were employed where applicable.

Significant climatic variations, as related to consumptive use of water, occur even within certain hydrographic units of the Central Coastal Area. For example, prevailing fogs and cool temperatures along the coast tend to reduce the consumption of water. In order to facilitate the estimating of irrigation consumptive use, therefore, the Lower Salinas and Santa Maria Hydrographic Units were divided into coastal and interior isoclimatic zones. Table 65 presents the estimated unit values of mean seasonal consumptive use of applied irrigation water and of precipitation on lands devoted to crops of the various groups.

Unit mean seasonal consumptive use of applied water on farm lots was estimated to be about 0.5 foot of depth. Estimates of unit mean seasonal consumptive use of precipitation on farm lots varied from 0.8 foot to 1.4 feet in the various hydrographic units of the Central Coastal Area, and averaged about 1.2 feet of depth. These estimates were employed for both present and probable ultimate conditions of development.

Urban and Suburban Water Use

Present unit seasonal values of use of water on urban and suburban water service areas of the Central Coastal Area were estimated largely on the basis of available records of delivery of water to the areas, as compiled by municipalities and other public water service agencies. Probable ultimate values of water deliveries were estimated by applying to the present values derived percentage factors to account for expected future increase in population densities and in per capita water use. Table 66 presents the estimates of present and probable ultimate unit seasonal values of gross water deliveries in urban and suburban water service areas. These values were assumed to be equivalent to consumptive use of applied water.

Use of Water in Other Water Service Areas

Unit values of water use on the miscellany of service areas grouped in this category were derived generally from measured or estimated present deliveries of water to the typical development involved. In most cases the estimates were made in terms of per capita use of water, and the actual acreage of the service

TABLE 65

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, CENTRAL COASTAL AREA

(In feet of depth)

Hydrographic unit		Alfalfa			Pasture			Orchard			Citrus			Vineyard		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Santa Cruz	-----	-----	-----	1.9	1.4	3.3	-----	-----	-----	-----	-----	-----	-----	-----	-----
2	San Benito	2.2	1.3	3.5	2.3	1.2	3.5	1.0	1.3	2.3	-----	-----	-----	0.5	1.1	1.6
3	Pajaro	1.7	1.5	3.2	1.9	1.3	3.2	0.6	1.3	1.9	-----	-----	-----	-----	-----	-----
4	Upper Salinas	2.2	1.2	3.4	2.3	1.1	3.4	1.1	1.2	2.3	-----	-----	-----	0.5	1.1	1.6
5	Lower Salinas															
	Coastal	2.2	1.0	3.2	2.2	0.9	3.1	1.0	0.9	1.9	-----	-----	-----	-----	-----	-----
	Interior	2.5	0.9	3.4	2.5	0.9	3.4	1.3	0.9	2.2	-----	-----	-----	-----	-----	-----
6	Carmel	1.7	1.5	3.2	2.0	1.2	3.2	0.6	1.3	1.9	-----	-----	-----	-----	-----	-----
7	Monterey Coast	-----	-----	-----	2.1	1.2	3.3	-----	-----	-----	-----	-----	-----	-----	-----	-----
8	San Luis Obispo	1.9	1.4	3.3	2.1	1.2	3.3	1.4	1.2	2.6				0.8	1.1	1.9
9	Carrizo Plains	2.8	0.8	3.6	2.8	0.8	3.6	2.1	0.8	2.9	-----	-----	-----	-----	-----	-----
10	Santa Maria															
	Coastal	2.0	1.2	3.2	2.0	1.2	3.2	1.5	1.2	2.7	-----	-----	-----	-----	-----	-----
	Interior	2.6	0.9	3.5	2.6	0.9	3.5	1.9	0.9	2.8	-----	-----	-----	1.1	0.9	2.0
11	Santa Ynez	2.1	1.2	3.3	2.2	1.1	3.3	1.5	1.1	2.6	1.1	1.1	2.2	-----	-----	-----
12	Santa Barbara	1.9	1.4	3.3	2.2	1.1	3.3	1.4	1.2	2.6	1.0	1.2	2.2	-----	-----	-----

TABLE 65—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, CENTRAL COASTAL AREA

(In feet of depth)

Hydrographic unit		Truck crops			Sugar beets			Miscellaneous field crops			Hay and grain		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Santa Cruz	0.5	1.2	1.7	-----	-----	-----	0.7	1.1	1.8	0.4	1.2	1.6
2	San Benito	1.0	1.0	2.0	1.3	1.0	2.3	1.2	0.9	2.1	0.4	1.2	1.6
3	Pajaro	0.6	1.0	1.6	0.9	1.1	2.0	0.6	1.0	1.6	-----	-----	-----
4	Upper Salinas	1.0	1.0	2.0	-----	-----	-----	1.1	1.0	2.1	0.4	1.2	1.6
5	Lower Salinas												
	Coastal	0.8	0.9	1.7	1.1	0.9	2.0	0.9	0.9	1.8	0.4	0.9	1.3
	Interior	1.1	0.9	2.0	1.3	0.9	2.2	1.2	0.9	2.1	0.4	0.9	1.3
6	Carmel	0.6	1.1	1.7	-----	-----	-----	0.8	1.0	1.8	-----	-----	-----
7	Monterey Coast	0.7	1.0	1.7	-----	-----	-----	0.9	1.0	1.9	0.4	1.0	1.4
8	San Luis Obispo	1.4	1.1	2.5	-----	-----	-----	1.4	1.1	2.5	0.7	1.1	1.8
9	Carrizo Plains	2.0	0.8	2.8	-----	-----	-----	2.0	0.8	2.8	0.6	0.8	1.4
10	Santa Maria												
	Coastal	1.5	1.0	2.5	1.0	1.0	2.0	1.5	1.0	2.5	0.7	1.0	1.7
	Interior	1.6	0.9	2.5	-----	-----	-----	1.1	0.9	2.0	0.5	0.9	1.4
11	Santa Ynez	1.5	1.0	2.5	1.1	1.0	2.1	1.5	1.0	2.5	0.7	1.0	1.7
12	Santa Barbara	1.4	1.0	2.4	-----	-----	-----	1.4	1.0	2.4	0.8	1.0	1.8

area was not a significant factor. In such cases the aggregate amount of water deliveries is relatively very small, and negligible recovery of return flow is involved. For purposes of study, therefore, the estimated unit values of delivery of water to these facilities were considered to be also the measures of consumptive use of applied water.

Both the National Forest and Park Services provided estimates of present and probable ultimate unit deliveries of water to all facilities within their jurisdiction. The estimates were generally in terms of per capita use of water, and were based on actual measurements and experience. They varied widely from place to place and in type of use, and for this reason are not detailed herein.

Records of delivery of water to private recreational areas in the Santa Cruz Mountains were available from local water service agencies. On an areal basis, unit values of water delivery are extremely low, averaging only about 0.05 foot of depth per season. Recovery of return flow is negligible, and unit deliveries of water were considered to be also the measures of consumptive use of applied water.

The value of unit use of water by military establishments was derived on a per capita basis, from available records of delivery of water and estimates

TABLE 66

ESTIMATED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY IN URBAN AND SUBURBAN AREAS, CENTRAL COASTAL AREA

(In feet of depth)

Hydrographic unit		Gross delivery of water*	
Reference number	Name	Present	Probable ultimate
1	Santa Cruz	0.9	0.7
2	San Benito	1.2	2.2
3	Pajaro	1.4	1.7
4	Upper Salinas	1.5	2.0
5	Lower Salinas	1.7	2.2
6	Carmel	0.5	2.0
7	Monterey Coast	0	1.7
8	San Luis Obispo	1.2	1.5
9	Carrizo Plains	0	1.5
10	Santa Maria	1.3	1.5
11	Santa Ynez	1.7	1.5
12	Santa Barbara	1.0	1.5

* Assumed equivalent to consumptive use of applied water.

of population of the camps involved. On these bases it was estimated that present consumptive use of applied water by such establishments averages about 75 gallons per capita per day. It was assumed that this value would hold in the future.

For other water service areas not encompassed by the foregoing specific types of water service, unit values of consumptive use of applied water under probable ultimate conditions of development were assigned on a per capita basis. In such areas, sparse residential, industrial, and recreational development is expected in the future. For areas outside national forests, monuments, and military reservations, it was estimated that the ultimate population density will average about eight persons per square mile, and that the per capita consumptive use of water will be about 70 gallons per day. In areas inside national forests, monuments, and military reservations the same per capita use estimates were made, but the population density was assumed to average about four persons per square mile. The period of water use was assumed to be of only three months' duration during the summer for areas above 3,000 feet in elevation, while water service for areas below 3,000 feet in elevation was assumed to be throughout the year.

CONSUMPTIVE USE OF WATER

In general, estimates of the amounts of water consumptively used in the Central Coastal Area were derived by applying appropriate unit values of water use to the service areas involved. The estimates represent the seasonal amount of consumptive use of water under mean conditions of water supply and climate. Table 67 presents estimates of present consumptive use of applied water and precipitation in areas having water service, and Table 68 presents corresponding estimates for probable ultimate conditions of development.

FACTORS OF WATER DEMAND

In addition to the amount of water consumptively used in a given service area, certain factors relating to the water requirements, such as necessary rates, times, and places of delivery of water, quality of water, losses of water, etc., have to be given consideration in the design of water development works. In the Central Coastal Area the most important of these demand factors are associated with the supply of water for irrigation. Of secondary importance are those related to the supply of water for urban, suburban, recreational, and other uses. The demand factors most pertinent to design of works to meet water requirements of the Central Coastal Area are discussed in the following sections.

TABLE 67

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, CENTRAL COASTAL AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Unclassified areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
1	Santa Cruz	2,700	5,800	100	7,300	300	10,400
2	San Benito	82,000	81,300	700	2,500	0	85,200
3	Pajaro	11,900	19,500	200	2,700	0	14,800
4	Upper Salinas	7,400	4,300	0	2,600	1,500	11,500
5	Lower Salinas	171,000	128,000	1,000	9,300	7,200	189,000
6	Carmel	1,100	1,400	0	8,100	0	9,200
7	Monterey Coast	negligible	negligible	0	negligible	100	100
8	San Luis Obispo	7,200	5,600	100	4,800	200	12,300
9	Carrizo Plains	0	0	0	0	0	0
10	Santa Maria	82,100	47,100	500	2,100	500	85,200
11	Santa Ynez	37,800	23,400	200	1,400	2,600	42,000
12	Santa Barbara	22,400	20,500	300	6,600	2,200	31,500
	APPROXIMATE TOTALS	426,000	337,000	3,100	47,400	14,600	491,000

TABLE 68

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, CENTRAL COASTAL AREA

(In acre-feet)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands: Applied water	Irrigated lands: Precipitation	Farm lots: Applied water	Urban and suburban areas: Applied water	Other water service areas: Applied water	Approximate total consumptive use of applied water
1	Santa Cruz	7,100	10,500	100	32,600	3,600	43,400
2	San Benito	163,000	166,000	1,400	11,700	600	176,000
3	Pajaro	19,700	29,700	300	8,300	0	28,300
4	Upper Salinas	352,000	325,000	2,100	9,800	2,100	366,000
5	Lower Salinas	270,000	220,000	2,000	40,700	7,300	320,000
6	Carmel	7,800	8,100	100	32,200	200	40,300
7	Monterey Coast	15,400	14,100	100	300	500	16,300
8	San Luis Obispo	88,900	71,700	500	14,700	400	104,000
9	Carrizo Plains	121,000	59,500	600	1,200	200	123,000
10	Santa Maria	209,000	154,000	1,300	9,000	1,500	221,000
11	Santa Ynez	130,000	108,000	800	5,300	2,400	139,000
12	Santa Barbara	48,000	47,100	500	32,600	4,400	85,500
	APPROXIMATE TOTALS	1,432,000	1,214,000	9,800	198,000	23,200	1,663,000

Monthly Distribution of Water Demands

Within the season, demand for irrigation water in the Central Coastal Area varies from little or none during the winter rainy months to more than 20 per cent of the seasonal total during dry summer months. Available information indicates that considerable variation in water demand also occurs with crop and soil types, and with distance from the coast. Urban water demands, while substantially higher in summer than in winter months, are far more uniform throughout the season than are those for irrigation. They vary from five to six per cent of the seasonal total during the months of December through March, to over ten per cent from June through September. Representative data on monthly distribution of irrigation and urban water demands in the Central Coastal Area are presented in Table 69.

Irrigation Water Service Area Efficiency

In study of irrigation water requirements of the Central Coastal Area it was found to be desirable to estimate the over-all efficiency of irrigation practice in the various service areas. Irrigation water service area efficiency was measured by the ratio of consumptive use of applied irrigation water to the gross amount of irrigation water delivered to a service area. Present irrigation water service area efficiencies were estimated after consideration of geologic conditions of the service areas involved, their topographic position in relation to sources of water supply and to other service areas, consumptive use of water, irrigation efficiency, usable return flow, and urban and suburban sewage outflow. Irrigation efficiencies, or the ratios of consumptive use of applied water to the total water applied, were determined from studies conducted by the Division of Water Resources for the Salinas Valley and the Pajaro area. Available information on irrigation practice in the Central Coastal Area indicates that present irrigation efficiencies generally range from 50 to 60 per cent. Additional factors affecting the estimates of probable ultimate irrigation water service area efficiencies were related to the location and extent of presently undeveloped irrigable lands, as well as to the increased cost of developing water. For purposes of illustra-

TABLE 69

DISTRIBUTION OF MONTHLY WATER DEMANDS, CENTRAL COASTAL AREA

(In per cent of seasonal total)

Locality and purpose	January	February	March	April	May	June	July	August	September	October	November	December	Total
Irrigation demand													
Pajaro Valley, 1947 and 1949	0.4	0.1	0.5	11.3	15.0	22.3	23.8	16.7	8.1	1.6	0.1	0.1	100.0
Salinas Valley Pressure Area, 1945	0	0	0	10.7	14.5	16.1	18.0	16.8	13.1	9.9	0.9	0	100.0
Santa Maria Valley, 1938	1.3	0.4	1.7	4.6	9.4	13.9	17.3	17.3	13.4	8.0	7.5	5.2	100.0
Urban demand													
Santa Cruz, 1946 through 1948	4.7	4.9	5.9	6.5	9.0	10.0	12.8	13.5	11.8	9.4	6.7	4.8	100.0
Salinas, 1944	6.7	5.7	6.0	7.5	9.6	10.5	10.6	10.4	9.8	8.8	7.6	6.8	100.0
Monterey, 1949	5.2	4.3	4.7	5.7	7.7	10.6	10.1	12.1	11.1	12.4	8.6	7.5	100.0
Santa Barbara, 1946 through 1952	6.0	5.7	5.9	6.9	8.0	9.7	10.9	11.6	11.2	9.4	8.3	6.4	100.0

tion, the weighted mean values of all irrigation water service area efficiencies within each hydrographic unit of the Central Coastal Area are presented in Table 70.

TABLE 70

ESTIMATED WEIGHTED MEAN IRRIGATION WATER SERVICE AREA EFFICIENCY WITHIN HYDROGRAPHIC UNITS, CENTRAL COASTAL AREA

(In per cent)

Hydrographic unit		Present	Probable ultimate
Reference number	Name		
1	Santa Cruz	50	50
2	San Benito	65	50
3	Pajaro	50	50
4	Upper Salinas	65	60
5	Lower Salinas	65	65
6	Carmel	50	50
7	Monterey Coast	-------	50
8	San Luis Obispo	60	50
9	Carrizo Plains	-------	65
10	Santa Maria	70	70
11	Santa Ynez	80	65
12	Santa Barbara	70	50

WATER REQUIREMENTS

As the term is used in this bulletin, water requirements refer to the amounts of water needed to provide for all beneficial uses of water and for irrecoverable losses incidental to such uses. Those water requirements of the Central Coastal Area that are primarily nonconsumptive in nature are discussed in general terms in the ensuing section. Following this, water requirements of the area that are consumptive in nature are evaluated, both for present and for probable ultimate conditions of development.

Requirements of a Nonconsumptive Nature

The principal nonconsumptive water requirements of the Central Coastal Area are associated with the preservation and propagation of fish and wildlife, flood control, and repulsion of sea water from ground water basins. For the most part, such requirements for water are extremely difficult to evaluate other than in conjunction with definite plans for water resource development. Their consideration in this bulletin, therefore, is limited to discussion of their implications as related to planning for future development of water resources.

So far as is known, there are no present requirements in the Central Coastal Area for water for generation of hydroelectric power nor for purposes of navigation. In view of prevailing water supply and topographic conditions, it cannot be foreseen that appreciable requirements of such nature will ever develop in the future.

Fish and Wildlife. The fresh-water fishery of the Central Coastal Area is limited as compared to that of some other parts of California. Nevertheless, it is important to the recreational economy of the area, and the fishing enjoyed by sportsmen contributes substantially to the State's recreational facilities.

Sport fishing is largely confined to the streams. However, there are several reservoirs and a number of farm ponds that also offer considerable fishing opportunities. The reservoirs and farm ponds are stocked for the most part with warm-water fishes, principally black bass, bluegill, and catfish, although a few contain trout.

The principal fishing is for adult steelhead rainbow trout that migrate annually from the sea to their spawning beds on the riffles of the fresh-water streams. Trout form resident populations in some of the suitable permanent stretches of streams in this area, and, along with the young of the steelhead and some silver salmon, contribute to the fishery. Adult silver salmon migrate into several of the streams from the Monterey Bay area northward, and provide some sport fishing, particularly in the San Lorenzo River. Adult silver salmon reared in these streams are also taken by both sport and commercial fishermen in the ocean.

The sport fishery in the streams of the Central Coastal Area could be greatly improved by maintenance of a suitable stream flow throughout the year. The runoff pattern of streams of the southern portion of the area is extremely erratic. Under present conditions, flow in some of the southern streams does not reach the ocean for periods up to several years. Maintenance of fish life sufficient for sport fishing in such streams as the Santa Ynez, Santa Maria, and Carmel Rivers would require the upstream impoundment of flood flows and their release during summer and fall to sustain stream flow. Whether this possible water requirement can be met, in view of the limited available water resources, is problematical. On the other hand, in the northern portion of the area, particularly in northern Santa Cruz County, local water resources considerably exceed probable ultimate requirements, and it is possible that flood flows may be conserved and later released to sustain stream flow for fishing during dry periods, without adversely affecting the economy of the area.

At the request of the Division of Water Resources, a series of estimates was made by the California Department of Fish and Game of the stream flow at certain points in the more important streams of the Central Coastal Area required for the protection and maintenance of fish life. These streams were divided into four classes by the Division, according to the anticipated degree of water development for various beneficial purposes that might compete with recreational or commercial fishing requirements. The summer and winter stream flow requirements for fish life in Central Coastal Area streams of the appropriate classes, as estimated by the Department of Fish and Game, are listed in Appendix F.

Although the mountains of the Central Coastal Area support a substantial wildlife and afford sport hunting to many tourists, the related water requirements are quite small. This condition is expected to be maintained in the indefinite future. Migratory waterfowl frequent the coastal lagoons, and provide minor opportunities for sport hunters. It is probable that such fresh water as is required to maintain this habitat will always be available from waste and return flows.

Flood Control. There is at present a material need for flood control in several localities of the Central Coastal Area, and it is anticipated that this need will increase with growth of the area. Only minor flood control works exist, and their effects on the developed water supply are extremely small. However, at least one major surface storage development involving flood control, the multipurpose San Lucas Project on the Salinas River, has been proposed. The presently authorized Winchester Ranch Reservoir, on the Nacimiento River, would offer substantial flood control benefits if operated as a multipurpose project. The Santa Maria Project is in the advanced planning stage. It includes the Vaquero Reservoir utilized for conservation and flood control, and the Santa Maria Valley levees for flood control. It is probable that additional projects of these types will be planned and constructed in the future. The nonconsumptive requirements for water imposed by such flood control works may be substantial, and must be given consideration in plans to meet water requirements.

Subsurface Outflow From Ground Water Basins to Ocean. In recent hydrologic studies in the Salinas and Pajaro Valleys it was found that during periods of little or no pumping draft on the confined aquifers of the coastal ground water basins there is substantial surface outflow to the ocean. This constitutes an unavoidable loss of the fresh-water supplies, and for purposes of inventory in the present investigation was construed as a nonconsumptive water requirement. It was estimated that the average subsurface outflow from the Salinas Valley, under the present pattern of pumping draft, is approximately 19,000 acre-feet per season, and from the Pajaro Valley approximately 2,000 acre-feet per season.

Overdrafts are known to exist in coastal ground water basins of the Pajaro and Salinas Valleys, and resultant sea-water intrusion into the confined aquifers is becoming a critical problem. Other coastal ground water basins of the Central Coastal Area have present or potential overdrafts, and are in danger of similar sea-water intrusion. Studies now in progress indicate that subsurface outflow of fresh water from the confined aquifers to the ocean must be maintained in order to control this invasion of the economically important ground water basins, and to prevent degradation of quality of the ground water. Evaluation of the magnitude of this water requirement must await detailed hydrologic analysis under a specific plan of development and pattern of pumping draft.

Requirements of a Consumptive Nature

Estimates of present and probable ultimate water requirements of a consumptive nature within hydrographic units of the Central Coastal Area are presented in Table 71. These mean seasonal values represent the amount of water other than precipitation needed to provide for beneficial consumptive use of water on irrigated lands, farm lots, urban and suburban areas, and other water service areas, and for

TABLE 71

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER, CENTRAL COASTAL AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots		Urban and suburban areas		Other water service areas		Approximate totals	
Reference number	Name	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate
1	Santa Cruz	5,400	14,200	100	200	7,300	32,600	300	3,600	13,100	50,600
2	San Benito	126,000	325,000	1,400	2,800	2,500	11,700	0	600	130,000	340,000
3	Pajaro	23,800	39,400	400	600	2,700	8,300	0	0	26,900	48,300
4	Upper Salinas	11,400	587,000	0	4,200	2,600	9,800	1,500	2,100	15,500	603,000
5	Lower Salinas	263,000	415,000	2,000	4,000	9,300	40,700	7,200	7,300	281,000	467,000
6	Carmel	2,200	15,600	0	200	8,100	32,200	0	200	10,300	48,200
7	Monterey Coast	0	30,800	0	200	0	300	100	500	100	31,800
8	San Luis Obispo	12,000	178,000	200	1,000	4,800	14,700	200	400	17,200	194,000
9	Carrizo Plains	0	187,000	0	1,200	0	1,200	0	200	0	190,000
10	Santa Maria	117,000	299,000	1,000	2,600	2,100	9,000	500	1,500	121,000	312,000
11	Santa Ynez	47,200	200,000	400	1,600	1,400	5,300	2,600	2,400	51,600	209,000
12	Santa Barbara	32,600	96,000	600	1,000	6,600	32,600	2,200	4,400	42,000	134,000
	APPROXIMATE TOTALS	641,000	*2,217,000	6,100	19,600	47,400	198,000	14,600	23,200	709,000	*2,458,000

* Total reduced by 170,000 acre-feet of return water in Lower Salinas Hydrographic Unit.

irrecoverable losses of water incidental to these uses. The estimates were derived from consideration of the heretofore presented estimates of consumptive use of applied water, and of water service area efficiencies of hydrographic units. In the Salinas Hydrographic Unit, extensive re-use in the lower unit of return water from the upper unit reduces the total requirement for the hydrographic unit as a whole.

Supplemental Requirements

The present supplemental water requirement in each hydrographic unit of the Central Coastal Area was taken as equivalent to the estimated ground water overdraft when such was known to exist. Deficiencies in surface stream flow or surface storage capacity were not considered in the estimates of present supplemental requirements. The difference between estimated present and probable ultimate water requirements for each hydrographic unit plus the present supplemental requirement was taken as the measure of the probable ultimate supplemental water requirement.

Results of prior studies of the use of ground water in the Central Coastal Area indicate that overdrafts exist in ground water basins of the San Benito, Pajaro, Lower Salinas, Santa Maria, and Santa Barbara Hydrographic Units. In all these instances the use of ground water has intensified since the date of studies, and probably the overdrafts in most basins have increased. However, lacking specific knowledge of the amount of such increases, the original estimates were used in this bulletin. The present use of water in the Santa Cruz, Upper Salinas, Carmel, Monterey Coast, Carrizo Plains, and Santa Ynez Hydrographic Units is primarily by stream diversion or by ground water pumpage, without apparent overdraft. In these instances the yield of the present water supply development was assumed to be equal to the present requirement for water. The Upper and Lower Salinas Hydrographic Units are unique in the Central Coastal Area because an increase in consumptive use of water in the upper unit will decrease water supplies naturally flowing to the lower unit. Therefore, for purposes of this bulletin, the values of supplemental water requirement for the Upper and Lower Salinas Hydrographic Units were estimated under the assumption that each unit is a separate entity, and that water is now imported from the upper unit to the lower unit to meet present requirements in the latter. Such an assumption permits ready modification of the estimates of supplemental requirements as future water resource development may be planned or occur. However, 70 percent of the water lost in transportation to and deep percolation from the Upper Salinas Hydrographic Unit would be available for re-use in the lower unit. Therefore, the total supplemental water requirement for the Salinas Basin is not necessarily the total of the supplemental requirements of the individual units.

Construction of the Cachuma Project in the Santa Ynez Hydrographic Unit is in progress. By storage of flood waters of the Santa Ynez River, it was estimated that an additional 33,000 acre-feet of safe seasonal yield of water will be made available for import to the Santa Barbara Hydrographic Unit. For purposes of this bulletin, present supplemental water requirements were estimated without consideration of this import. However, it was assumed that under conditions of ultimate development the Cachuma Project would furnish the indicated import to the Santa Barbara Hydrographic Unit.

Presented in Table 72 are the estimates of present and probable ultimate mean seasonal supplemental water requirement of hydrographic units of the Central Coastal Area.

TABLE 72

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS, CENTRAL COASTAL AREA

(In acre-feet)

Hydrographic unit		Present	Probable ultimate
Reference number	Name		
1	Santa Cruz	0	38,000
2	San Benito	15,000	225,000
3	Pajaro	4,000	25,000
4	Upper Salinas	0	588,000
5	Lower Salinas	80,000	266,000
6	Carmel	0	38,000
7	Monterey Coast	0	32,000
8	San Luis Obispo	0	177,000
9	Carrizo Plains	0	190,000
10	Santa Maria	55,000	246,000
11	Santa Ynez	0	158,000
12	Santa Barbara	30,000	89,000
	APPROXIMATE TOTALS	184,000	*1,902,000

* Total reduced by 170,000 acre-feet of return water in Lower Salinas Hydrographic Unit.

CHAPTER VI

SOUTH COASTAL AREA

The South Coastal Area, designated Area 4 on Plate 8, lies between latitudes 32.5° N. and 35° N., and comprises the drainage areas of those streams discharging into the Pacific Ocean between the southeastern boundary of the Rincon Creek watershed near the Santa Barbara-Ventura county line on the north and the Mexican boundary on the south. The portion of the drainage basin of the Tia Juana River lying within Mexico is not included in the area. All of Orange County and portions of the Counties of Kern, Los Angeles, Riverside, San Bernardino, San Diego, Santa Barbara, and Ventura lie within the boundaries of the South Coastal Area. The principal urban centers constitute the large metropolitan areas within and adjacent to the Cities of Los Angeles and San Diego.

To aid in hydrologic analyses, the South Coastal Area was subdivided into 10 hydrographic units, as delineated on Plate 8. The boundaries of these units generally follow topographic divides, with the exception of certain boundaries of the Los Angeles and San Diego Hydrographic Units, also termed the Los Angeles and San Diego Metropolitan Areas, which were selected on the basis of the probable ultimate limits of intensive urbanization. Table 73 lists the 10 hydrographic units and their areas, and Table 74 presents the area of the portion of each county included within the South Coastal Area.

The climate of the South Coastal Area is characterized in the coastal regions by relatively mild temperatures and light precipitation, and in the more inland regions by somewhat wider temperature variations and greater precipitation. Precipitation generally increases with elevation. The mean seasonal depth of precipitation at Los Angeles is about 15 inches, while at Kelly's Camp, at an elevation of 8,300 feet in the San Bernardino Mountains near the Los Angeles-San Bernardino county line, it is over 40 inches. Depth of seasonal precipitation on valley floor areas averages about 15 inches, varying from about 10 inches to 20 inches, with valley floor areas adjacent to the mountains receiving the higher rainfall. Variation of precipitation from season to season is quite pronounced. At Los Angeles an unbroken precipitation record has been maintained since 1877. During this period the seasonal depth of precipitation has varied between extremes of 5.59 inches and 38.18 inches, averaging 15.43 inches. Precipitation occurs principally during the winter months, about 90 per cent of the seasonal total generally occurring from November through April.

TABLE 73

AREAS OF HYDROGRAPHIC UNITS, SOUTH COASTAL AREA

Hydrographic unit: Reference number	Hydrographic unit: Name	Acres
1	Ventura	168,000
2	Santa Clara-Calleguas	1,286,000
3	Malibu	137,000
4	San Gabriel Mountains	307,000
5	Upper Santa Ana	1,450,000
6	Los Angeles	1,186,000
7	San Juan Capistrano	322,000
8	Santa Margarita-San Luis Rey	849,000
9	San Dieguito-Cottonwood	973,000
10	San Diego	317,000
	APPROXIMATE TOTAL	6,995,000

TABLE 74

AREAS OF COUNTIES WITHIN BOUNDARIES OF SOUTH COASTAL AREA

County	Acres
Kern	1,300
Los Angeles	1,768,000
Orange	503,000
Riverside	1,198,000
San Bernardino	647,000
San Diego	1,939,000
Santa Barbara	5,100
Ventura	934,000
APPROXIMATE TOTAL	6,995,000

The estimated mean seasonal natural runoff of streams in the South Coastal Area is about 1,227,000 acre-feet, or approximately 1.7 per cent of that for the entire State. The principal streams are the Ventura, Santa Clara, Los Angeles, San Gabriel, Santa Ana, Santa Margarita, San Luis Rey, San Dieguito, San Diego, and Tia Juana Rivers, which contribute a seasonal runoff of about 1,000,000 acre-feet on the average, or over 80 per cent of the total for the area. The largest stream, the Santa Ana River, has a mean seasonal runoff of 322,000 acre-feet, or about 26 per cent of the total for the South Coastal Area. Runoff is derived principally from rainfall and is characterized by high peak flows of short duration. Many streams are intermittent, with practically all runoff occurring during the winter and spring months. For the area as a whole approximately 70 per cent of the

Urban Growth in Los Angeles Metropolitan Area

Courtesy Spence Air Photos

runoff occurs during the four months from January through April on the average.

As shown on Plate 4, a total of 43 valley fill areas, which may or may not contain usable ground water, has been identified in the South Coastal Area. The most important of these from the standpoint of ground water utilization, are the basins located in the Upper Santa Ana, San Gabriel, and San Fernando Valleys, along the Santa Clara River and in the coastal plain at its mouth, and in the coastal plains of Los Angeles and Orange Counties. Practically all of the present regulation of runoff of the Santa Clara, Los Angeles, San Gabriel, and Santa Ana Rivers is provided by these ground water basins. In general, aquifers of economic significance in ground water basins adjacent to the coast are confined by overlying impervious strata, while those in basins farther inland contain free ground water. Many of the ground water basins have experienced overdraft for many years past, and in most of the important basins adjacent to the coast overpumping has lowered piezometric levels below sea level, with resultant intrusion of sea water.

Today the South Coastal Area is characterized by a rich and intensively irrigated agricultural development, by very large urban centers, and by an industrial development of national significance. The history of these developments dates back to the founding of the Spanish missions nearly two centuries ago.

The first practice of irrigation in the South Coastal Area came with the founding of San Diego Mission by the Franciscan Fathers in 1769. Water from the San Diego River, originally obtained by surface diversion and later supplemented by wells dug in the river gravels, was used to irrigate fields surrounding the mission. Similar agricultural developments accompanied the establishment of the Missions San Luis Rey, San Juan Capistrano, San Gabriel, San Fernando, and San Buenaventura in ensuing years. In 1833 the missions were secularized by the Mexican Government and the mission holdings and other lands were given to individuals in the form of large land grants, which were used primarily for raising livestock. For many years after the secularization of the missions, there was no significant increase in the practice of growing irrigated crops. It was not until the latter half of the nineteenth century that significant expansion of irrigated lands commenced. In 1851 the Mormons purchased the Rancho San Bernardino and soon were irrigating several hundred acres. During the following years, plantings of irrigated crops were made in many other parts of the South Coastal Area. Citrus crops were first raised commercially in the Upper Santa Ana Valley, and shipment of oranges to the east began in the 1880's. Walnuts were first planted in Ventura County about 1889, and bean production began in the Oxnard Plain of this county in the 1890's. Winter truck crops were first produced commercially near San Diego about 1910, and in about 1915 avocados and other subtropical fruits were introduced to this county. Figures published by the United States Bureau of the Census indicate that over 200,000 acres were irrigated in the South Coastal Area in 1900. By 1930, this figure had increased to over 600,000 acres. Since 1930 the area devoted to irrigated agriculture has remained fairly constant, the present gross irrigated area being about 650,000 acres, located chiefly on the coastal plains and in the interior valleys where water supplies have been available. The most important crops presently include citrus and subtropical fruits, truck, nuts, alfalfa, and pasture.

The principal centers of urban development are the Cities of Los Angeles and San Diego and adjacent areas, and the urban zone in the Upper Santa Ana Valley from Pomona to San Bernardino. Table 75 presents the 1940 and 1950 populations of the eight largest cities in the South Coastal Area according to the federal census, and 1954 population estimates. The 1954 populations shown for San Diego and San Bernardino are estimates by the planning commissions of these cities. The 1954 populations shown for the remaining cities are estimates by the Los Angeles County Regional Planning Commission, as of July, 1954. It should be noted that the estimated 1954 population of the City of San Diego includes about 63,000 military personnel.

The historical growth of the City of Los Angeles is generally indicative of urban growth in the South Coastal Area. In 1850, four years after the occupation of Los Angeles by Americans, the population was only 1,610. However, by 1880 the population had increased to over 10,000. As a result of many factors, including the mild climate, a direct rail connection to the east, and the construction of Los Angeles Harbor in the 1880's, the population grew to over 50,000 in 1890, and to over 100,000 in 1900. The rate of growth accelerated during the early decades of the present century, and, as shown in Table 75, the 1954 population of Los Angeles was estimated to be over 2,000,000.

TABLE 75

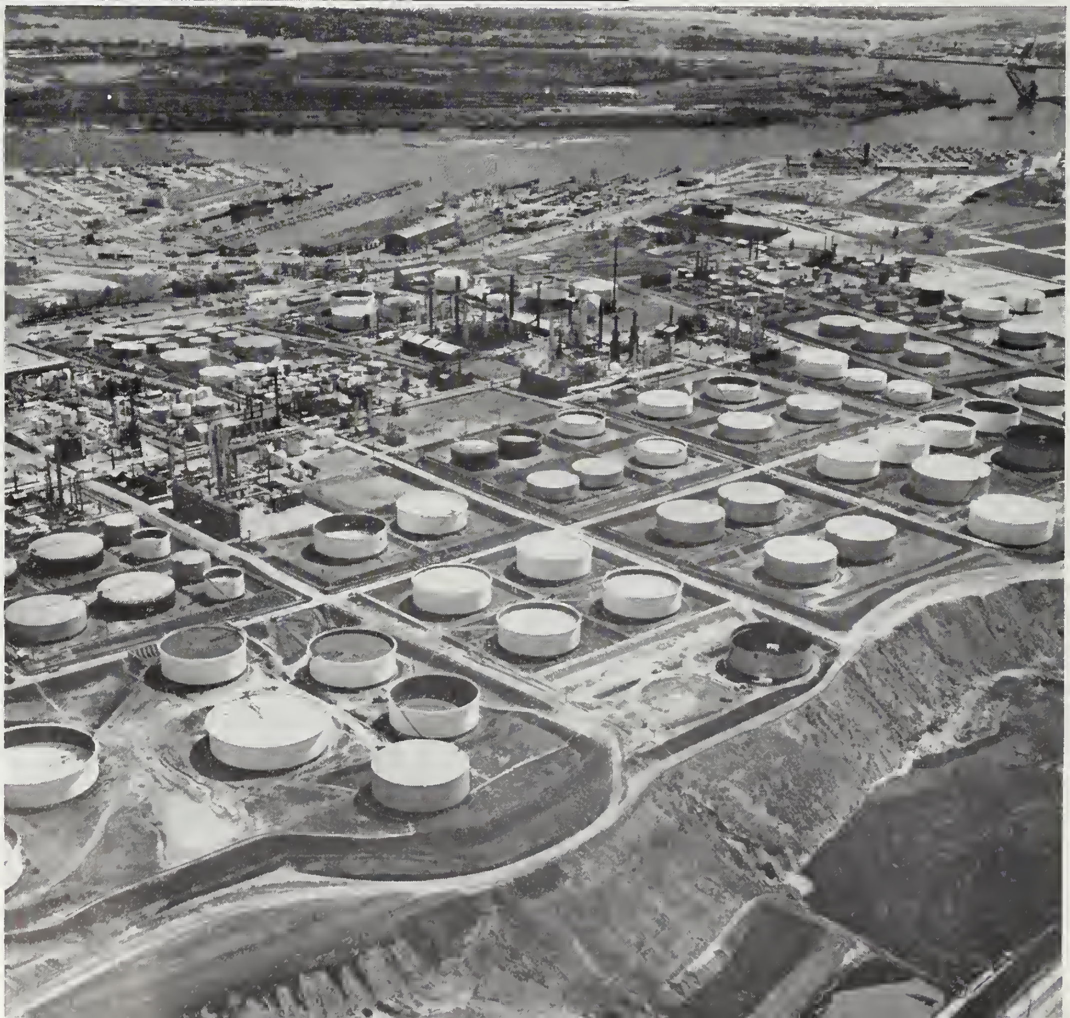
POPULATION OF PRINCIPAL URBAN CENTERS, SOUTH COASTAL AREA

City	1940 census	1950 census	1954 estimate
Los Angeles	1,504,000	1,970,000	2,138,000
San Diego	203,000	334,000	459,000
Long Beach	164,000	251,000	283,000
Pasadena	81,900	105,000	116,000
Glendale	82,600	95,700	114,000
Burbank	34,300	78,600	91,000
Santa Monica	53,500	71,600	76,000
San Bernardino	43,600	63,100	81,000

Construction of excellent rail and port facilities, the discovery of oil, and the availability of a large labor pool, were important factors in the development of

Los Angeles Harbor

Courtesy State Division of Highways



The Petroleum Industry in the South Coastal Area

Courtesy State Division of Highways

Los Angeles as an industrial center. Industrialization commenced largely in the years following the first World War, and was given even greater impetus by World War II. The 1947 Census of Manufactures by the United States Department of Commerce indicated that Los Angeles ranked fifth among cities of the United States in value added by manufacturing. It has been estimated that in 1953 the Counties of Los Angeles and Orange ranked third among industrial areas of the Nation, and that nearly one-third of the over two million employed persons in the two counties were engaged in manufacturing enterprises. Among the principal industries are automobile assembly, motion picture production, food processing, petroleum production and refining, and the manufacture of aircraft, tires, apparel, and furniture. Associated with this industrial growth has been the growth of Los Angeles Harbor, which presently handles a total tonnage exceeding that of any other Pacific Coast port.

The historical population growth of the City of San Diego followed a similar pattern to that of Los Angeles. The growth was slow until the latter part of the nineteenth century, being in large part retarded by lack of sufficient firm water supplies and adequate transportation facilities. The population of the city in 1880 was less than 3,000. However, in the ensuing decade the entrance of the first railroad into the area, and the initiation of several water development plans, overcame these handicaps, and the population had grown to over 16,000 by 1890. After about 15 years of relative stability, the city then began a generally steady but frequently accelerated growth. This growth was influenced by the efforts of "booster" clubs which were first organized about 1900, by the publicity created by the world expositions held there in 1915 and 1935, and by the expansion of military establishments and aircraft manufacturing occasioned by World War II.

The large population centers of the South Coastal Area, and the tourist trade attracted to these centers, have occasioned the establishment of many resort and recreational areas, principally in the mountains and along the coast. Many of the mountain recreational areas are located within the boundaries of the Los Padres, Angeles, San Bernardino, and Cleveland National Forests, and many of the beach areas are under the jurisdiction of the Division of Beaches and Parks of the State Department of Natural Resources.

There are numerous military reservations in the area, the most important of which are under Department of the Navy jurisdiction. These include training, air, and repair facilities at San Diego, several marine bases, the largest of which is Camp Pendleton, and two major bases in Ventura County, the larger being a guided missile test center. Army and Air Force establishments are distributed through the area, and the principal installation is March Air Force Base in Riverside County.

The most significant recent trend in land use within water service areas of the South Coastal Area has been the urbanization which is still occurring at a rapid rate. This development has largely taken place on agricultural lands immediately adjacent to existing urban areas. It is considered probable that most of the future urbanization will also occur on lands presently devoted to agricultural use. Increase in the area of irrigated lands will probably be dependent upon the availability of additional water supplies developed outside the South Coastal Area, and will occur both by application of water to areas presently dry farmed, and by bringing under cultivation lands not presently farmed due to lack of an adequate water supply. A proportional increase in areas devoted to recreation will undoubtedly accompany future increases in population.

At the present time the principal water supplies in the South Coastal Area are obtained by pumping from underlying ground water basins, diversion from surface reservoirs, and importation of water from the Colorado River and from the Owens River and Mono Basin. Although large amounts of water are obtained by individuals who pump from ground water, most of the lands requiring water are served by a multitude of agencies, both large and small. The principal water service agencies in the South Coastal Area, and the number of domestic services and irrigated areas served by each, are listed in Appendix B.

The earliest development of water supplies in the South Coastal Area consisted of the diversion of natural flow of streams, supplemented by wells dug in the river gravels. The water so obtained was conveyed to nearby places of use by ditch systems, of which remnants still exist. Because of the erratic nature of the natural stream flow, these unregulated sources of supply were found to be inadequate to serve the increasing needs for water in the latter years of the nineteenth century. In 1884, Bear Valley Reservoir was constructed on a tributary of the Santa Ana River. This marked the first significant use of surface storage to regulate water supplies in the South Coastal Area. Although extensive control of surface supplies has taken place subsequently, the underlying ground water basins have become the most important source of supply in the Upper Santa Ana, San Fernando, and San Gabriel Valleys, in the coastal plains of Los Angeles and Orange Counties, and throughout Ventura County. Prior to 1900 thousands of wells, many of them artesian, were developed to supply both irrigation and domestic needs. As draft on the ground water supplies increased, the limits of artesian areas decreased in size and ground water levels began dropping, resulting in an increasing use of deep-well turbine pumps to extract water from greater depths. At the present time, by far the largest portion of local supplies used in the Santa Clara-Calleguas, Los Angeles, and Upper Santa Ana Hydrographic Units continues to be obtained by pumping from ground water.

Ground water basins in San Diego County are of lesser importance as a source of water supply, because of their insufficient storage capacity to provide the desired degree of regulation of the erratic stream flow. Therefore, water users were soon forced to turn to surface storage developments to supply their increasing needs. The first plans for storage developments were initiated by numerous small companies, which seldom had a life of more than a few years. Cuyamaca Reservoir was constructed in 1887 by the San Diego Flume Company, and Sweetwater Reservoir in 1888 by the San Diego Land and Town Company. Since that date, Morena, Lower Otay (formed by Savage Dam), Hodges, Barrett, Henshaw, El Capitan, San Vicente, Loveland, and Sutherland Reservoirs have been constructed by various organizations to meet increasing water requirements. At the present time, Cuyamaca Reservoir is owned by the La Mesa, Lemon Grove and Spring Valley Irrigation District; Sweetwater and Loveland Reservoirs by the California Water and Telephone Company, and Lake Henshaw by the Vista Irrigation District. Of the remaining cited reservoirs, all of which are presently owned by the City of San Diego, Morena and Lower Otay were purchased from the Southern California Mountain Water Company in 1913, Hodges was purchased from the San Diego County Water Company in 1925, and Barrett, El Capitan, San Vicente, and Sutherland were constructed by the city. The smallest of the foregoing reservoirs in San Diego County, Cuyamaca, has a storage capacity of about 11,600 acre-feet, and the largest, Lake Henshaw, has a capacity of about 194,000 acre-feet. Their aggregate storage capacity is about 677,000 acre-feet.

As early as 1900 it became apparent that local water supplies would not be sufficient to satisfy the needs of the rapidly growing City of Los Angeles, and studies were begun to locate additional sources of water. After several years of investigation, the city authorized construction of an aqueduct from the Owens River in the Lahontan Area. Construction of the Los Angeles Aqueduct was initiated on September 20, 1907, and was completed on November 5, 1913. The initial project included diversion structures and a 233-mile conduit to the San Fernando Valley. In 1910, additional bonds were issued for the purpose of financing the generation of electric power along the aqueduct. In 1940, the system was extended northward to the Mono Basin, and subsequently water from this watershed has been conveyed through the aqueduct. The present average capacity of the Los Angeles Aqueduct is estimated to be about 320,000 acre-feet per season.

During the decade from 1920 to 1930, the City of Los Angeles and other communities in southern California foresaw the need of additional supplemental water for their rapidly expanding service areas. Studies of the possibilities of importing Colorado River water were initiated by the Los Angeles Department of Water and Power, and in 1928 were turned over to the newly formed Metropolitan Water District of Southern California. After extensive studies of possible alternative conduit routes to the South Coastal Area, a final alignment was selected and construction was started in 1933. First delivery of water from the Colorado River Aqueduct was made in 1941 to the City of Pasadena. Waters of the Colorado River, regulated by Lake Mead created by Hoover Dam, are diverted to the aqueduct from Lake Havasu behind Parker Dam. From Lake Havasu, the conduit extends in a generally westerly direction a distance of 242 miles to terminal storage in Lake Mathews, near Riverside, and thence northwesterly about 38 miles to the La Verne softening plant in Upper San Gabriel Valley.

Under the provisions of the Colorado River Compact and the Boulder Canyon Project Act, the State of California claims the right to 5,362,000 acre-feet of water from the Colorado River each year. By the terms of the 1931 Seven-Party Water Agreement, executed by California agencies using Colorado River water, the Metropolitan Water District of Southern California was allotted 1,100,000 acre-feet of this amount, and an additional 112,000 acre-feet were allotted to the City and County of San Diego. A contract with the Secretary of the Interior, signed in 1930, and amended in 1931, provides for delivery to the district of their entitlements under the provisions of the Seven-Party Water Agreement. During the fiscal year 1949-50, which is the period upon which present requirements tabulated in this bulletin are based, about 165,000 acre-feet of Colorado River water were delivered to member agencies by the district. The rights of the City and County of San Diego were merged upon the formation of the San Diego County Water Authority on June 9, 1944, which latter agency became a member of the Metropolitan Water District on December 17, 1946. The year 1947 saw the completion of the first barrel of the San Diego Aqueduct. The aqueduct takes water from the Colorado River Aqueduct at a point in San Jacinto Valley, and conveys it to San Vicente Reservoir on a tributary of the San Diego River. The second barrel of the San Diego Aqueduct was dedicated on October 2, 1954, and it is estimated by the San Diego County Water Authority that the capacity of the aqueduct is now approximately 215 second-feet.

Plate 15 depicts the historical import of water to the South Coastal Area by the City of Los Angeles and the Metropolitan Water District of Southern California.

In summary, it should be emphasized that despite the presence of a tremendous urban and industrial development, agriculture remains a major economic activity of the South Coastal Area. Water requirements for other uses, however, are expected to surpass that for agriculture in the near future. The current encroachment of urban types of development onto agricultural lands will undoubtedly continue in the future. In addition, large areas of irrigable lands presently in the native state will probably be brought under cultivation if and when new sources of water supply become available. In order for the South Coastal Area to be able to realize its large potential, additional water must be made available, probably from sources outside the area.

In this connection, it has been found that urbanization of an area previously occupied by irrigated agriculture significantly affects the water requirements of the area. When irrigated agriculture is superseded by an unsewered urban area, and there is opportunity for re-use of the unconsumed portion of the applied water, urban requirements may be slightly less than those for the formerly irrigated area. Export of sewage to the ocean, however, may increase the urban requirement substantially over that previously necessary for the maintenance of irrigated agriculture.

At present, there is no water utilized in the South Coastal Area for navigation, and but negligible amounts are utilized for hydroelectric power generation and for the preservation and propagation of fish and wildlife. These conditions are expected to maintain in the future. There have been large public expenditures for flood protection, and there is in excess of 400,000 acre-feet of storage capacity in existing flood control reservoirs, the largest being Prado on the Santa Ana River with a storage capacity of 223,000 acre-feet. Many miles of stream channel are lined for flood control purposes, and the extension of such improvement is planned for the future. Additional flood control works will be necessary in the future to protect the intensive urban and agricultural developments.

The remainder of this chapter presents available data and estimates concerning the nature and extent of present and probable ultimate water requirements in the South Coastal Area.

PRESENT WATER SERVICE AREAS

As a necessary step in estimating present water requirements in the South Coastal Area, determination was made of the location, nature, and extent of present irrigated and urban and suburban water service areas. In the remainder of the area, relatively minor miscellaneous water service areas were not classified in detail regarding area and type of use, but consideration was given to this water service in estimating the present water requirement.

Irrigated Lands

It was determined that an average of about 617,000 acres in the South Coastal Area are irrigated each year under present conditions of development. This constitutes about 9 per cent of the total irrigated lands in California. There are large acreages of citrus and subtropical fruits throughout the area, these crops occupying nearly half of all the irrigated lands. Truck crops are produced in large quantity in the Upper Santa Ana Valley and in the Los Angeles Metropolitan Area, and to a lesser extent in the remainder of the South Coastal Area. Other important irrigated crops are nuts, alfalfa, pasture, and beans.

The determination of areas devoted to irrigated agriculture was based upon land use surveys conducted by the Division of Water Resources during the years from 1948 to 1951, and recent land use surveys made by other public agencies. Dates of field mapping and sources of data are included in Appendix D. The crop grouping employed to segregate crops of similar water use varied somewhat in the various surveys. For purposes of presentation in this bulletin, the crops were generally grouped as follows:

Alfalfa	Hay, seed, and pasture
Pasture	Grasses and legumes, other than alfalfa, used for livestock forage, and irrigated grass in parks, cemeteries, golf courses, etc.
Walnuts	
Orchard	Deciduous fruit, olives, and nuts other than walnuts
Citrus and subtropical	Oranges, lemons, grapefruit, and avocados
Truck crops	Intensively cultivated fresh vegetables, including tomatoes, lettuce, artichokes, brussels sprouts, cabbages, carrots, peppers, broccoli, corn, beets, and berries.
Beans	All varieties of dry beans
Hay and grain	Hay other than alfalfa and all grain crops
Miscellaneous	Other crops, including nursery, flowers, and vineyards.

A deviation from the above crop grouping occurs in the Upper Santa Ana Valley and the Los Angeles Metropolitan Area, where beans were included as a part of the truck classification.

The areas presently devoted to irrigated agriculture in hydrographic units of the South Coastal Area

Urban Development and
Agriculture Near
San Bernardino

*Courtesy San Bernardino
County Board of Trade*

Irrigated Lands in
Ventura County

are summarized in Table 76. Table 77 lists the irrigated areas by counties. Areas presented in the two tables include irrigated agricultural lands within the boundaries of federal reservations, such as military reservations, Indian reservations, and national forests.

Urban and Suburban Water Service Areas

The gross area presently occupied by urban and suburban types of land use in the South Coastal Area was determined to be about 550,000 acres. In most hydrographic units of the area detailed surveys were made as to the lands devoted to the various urban and suburban types of land use. However, in the San Juan Capistrano, Santa Margarita-San Luis Rey, and San Dieguito-Cottonwood Hydrographic Units no detailed segregation of the urban and suburban lands by land use type was made, and only the total urban and suburban area was determined. The San Gabriel Mountains Hydrographic Unit lies entirely within the Angeles National Forest, and areal figures for land use other than irrigated agriculture were not obtained.

Since in most of the area a differentiation between farm lots and the suburban type of land use was almost impossible, farm lots were included in the area mapped as rural residence, and were tabulated with the present urban and suburban area. Also, since in many cases the urban and suburban areas in military reservations were mapped in accordance with their specific type of land use, these areas were tabulated with urban and suburban water service areas.

Tables 78 and 79 list the areas presently occupied by urban and suburban types of land use in hydrographic units and counties, respectively, of the South Coastal Area. Due to the varying land use classifications employed in different surveys, these classifications were combined into the categories of residential, commercial, industrial, miscellaneous, and lands not requiring water service, for presentation in this bulletin. The miscellaneous areas include lands occupied by schools, institutions, rural residences, dairies, hog farms, chicken ranches, and urban types of military areas. Areas listed as not requiring water service consist of inclusions in the gross urban area of streets, vacant lands, oil fields, etc.

TABLE 76

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, SOUTH COASTAL AREA

(In acres)

Hydrographic unit		Alfalfa	Pasture	Orchard	Walnuts	Citrus and subtropical	Truck crops	Beans	Hay and grain	Miscellaneous crops	Approximate net irrigated area	Included nonwater service areas	Approximate gross area
Reference number	Name												
1	Ventura	200	300	200	600	2,400	200	0	0	0	3,900	200	4,100
2	Santa Clara-Calleguas	8,600	1,400	600	17,300	40,500	10,200	33,300	800	400	113,000	5,900	119,000
3	Malibu	0	300	0	0	100	500	0	0	0	900	100	1,000
4	San Gabriel Mountains	0	0	100	0	0	200	0	0	0	300	0	300
5	Upper Santa Ana	12,900	16,900	13,900	13,600	81,000	32,200	0	12,200	6,000	189,000	9,700	198,000
6	Los Angeles	15,200	16,600	2,700	10,100	122,000	67,300	-------	3,600	3,500	241,000	12,700	254,000
7	San Juan Capistrano	300	100	0	100	2,800	1,100	1,300	0	300	6,000	600	6,600
8	Santa Margarita-San Luis Rey	2,800	2,300	600	600	8,000	4,300	100	3,100	700	22,500	1,800	24,300
9	San Dieguito-Cottonwood	1,000	1,700	1,200	400	14,700	1,600	0	100	300	21,000	2,100	23,100
10	San Diego	1,500	1,600	400	200	8,000	7,100	300	0	400	19,500	1,900	21,400
	APPROXIMATE TOTALS	42,500	41,200	19,700	42,900	279,000	125,000	35,000	19,800	11,600	617,000	35,000	652,000

TABLE 77

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN COUNTIES, SOUTH COASTAL AREA

(In acres)

County	Alfalfa	Pasture	Orchard	Walnuts	Citrus and subtropical	Truck crops	Beans	Hay and grain	Miscellaneous crops	Approximate net irrigated area	Included nonwater service areas	Approximate gross area
Los Angeles	14,400	14,200	2,700	9,700	59,000	27,700	----------	3,400	3,400	135,000	7,100	142,000
Orange	5,800	3,600	500	2,000	73,300	43,300	----------	700	300	129,000	7,000	136,000
Riverside	11,600	10,900	7,400	6,300	26,300	18,100	0	12,000	2,800	95,400	4,700	100,000
San Bernardino	3,200	6,600	6,600	6,000	47,300	14,100	0	2,800	3,200	89,800	4,700	94,500
San Diego	3,300	4,500	2,000	1,100	30,700	13,400	1,700	100	1,700	58,500	5,700	64,200
Ventura	4,200	1,400	500	17,800	43,000	8,100	33,300	800	200	109,000	5,800	115,000
APPROXIMATE TOTALS	42,500	41,200	19,700	42,900	279,000	125,000	35,000	19,800	11,600	617,000	35,000	652,000

TABLE 78

PRESENT URBAN AND SUBURBAN AREAS WITHIN HYDROGRAPHIC UNITS, SOUTH COASTAL AREA

(In acres)

Hydrographic unit		Area requiring water service					Area not requiring water service	Approximate gross area
Reference number	Name	Residential	Commercial	Industrial	Miscellaneous	Subtotal		
1	Ventura	1,600	200	400	500	2,700	4,800	7,500
2	Santa Clara-Calleguas	4,000	600	400	3,300	8,300	13,500	21,800
3	Malibu	500	100	0	100	700	800	1,500
4	San Gabriel Mountains							
5	Upper Santa Ana	28,000	4,000	3,100	1,100	36,200	26,700	62,900
6	Los Angeles	163,000	19,600	20,200	41,500	244,000	155,000	399,000
7	San Juan Capistrano				1,800	1,800	700	2,500
8	Santa Margarita-San Luis Rey				3,100	3,100	1,400	4,500
9	San Dieguito-Cottonwood				2,700	2,700	1,200	3,900
10	San Diego	17,800	1,800	300	5,300	25,200	18,100	43,300
	APPROXIMATE TOTALS	215,000	26,300	24,400	59,400	325,000	222,000	547,000

TABLE 79

PRESENT URBAN AND SUBURBAN AREAS WITHIN COUNTIES, SOUTH COASTAL AREA

(In acres)

County	Area requiring water service	Area not requiring water service	Approximate gross area
Los Angeles	237,000	148,000	385,000
Orange	15,300	12,700	28,000
Riverside	14,200	9,100	23,300
San Bernardino	19,300	15,200	34,500
San Diego	31,000	20,600	51,600
Ventura	8,600	16,400	25,000
APPROXIMATE TOTALS	325,000	222,000	547,000

Unclassified Areas

The remainder of the South Coastal Area, comprising those lands not included in either the irrigated or urban and suburban classifications as regards water service, constitutes about 5,800,000 acres, or over 80 per cent of the total land area. Included in these remaining lands are about 1,200 acres actually requiring water service at the present time, but which were not classified in detail as to the nature of their water utilization.

Portions of the Los Padres, Angeles, San Bernardino, and Cleveland National Forests, occupying an area of about 3,200 square miles, or about 2,000,000 acres, are included within the boundaries of the South Coastal Area. An estimated 5,900 acres of irrigated agriculture in the national forests, lying primarily along the lower slopes of the mountains and within the mountain valleys, are included in the figures of Tables 76 and 77. Unclassified lands in the national forests requiring water service include camp grounds and other developed areas, which may have substantial water requirements during the summer months.

There are 31 beaches and parks, including about 37,000 acres, in the South Coastal Area maintained by the Division of Beaches and Parks of the State Department of Natural Resources. The relatively small developed areas of these recreational facilities, like the recreational areas in the national forests, do not have a sustained annual demand for water but do require a supply during the summer months for domestic service for camp and picnic areas.

Summary

Present water service areas within hydrographic units of the South Coastal Area are summarized in Table 80, and present water service areas within the counties in Table 81.

TABLE 80

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS, SOUTH COASTAL AREA

(In acres)

Hydrographic unit		Irrigated lands	Urban and suburban areas	Approximate total
Reference number	Name			
1	Ventura	4,100	7,500	11,600
2	Santa Clara-Calleguas	119,000	21,800	141,000
3	Malibu	1,000	1,500	2,500
4	San Gabriel Mountains	300		300
5	Upper Santa Ana	198,000	62,900	261,000
6	Los Angeles	254,000	399,000	653,000
7	San Juan Capistrano	6,600	2,500	9,100
8	Santa Margarita-San Luis Rey	24,300	4,500	28,800
9	San Dieguito-Cottonwood	23,100	3,900	27,000
10	San Diego	21,400	43,300	64,700
	Subtotals	652,000	547,000	1,199,000
	Unclassified areas receiving water service			1,200
	APPROXIMATE TOTAL			1,200,000

TABLE 81

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN COUNTIES, SOUTH COASTAL AREA

(In acres)

County	Irrigated lands	Urban and suburban areas	Approximate total
Los Angeles	142,000	385,000	527,000
Orange	136,000	28,000	164,000
Riverside	100,000	23,300	123,000
San Bernardino	94,500	34,500	129,000
San Diego	64,200	51,600	116,000
Ventura	115,000	25,000	140,000
Subtotals	652,000	547,000	1,199,000
Unclassified areas receiving water service			1,200
APPROXIMATE TOTAL			1,200,000

PROBABLE ULTIMATE WATER SERVICE AREAS

To aid in estimating ultimate water utilization in the South Coastal Area, projections were first made to determine the probable ultimate areal extent of irrigated crops and of urban and suburban types of land use. It was assumed that the remainder of the area, referred to as "other water service areas," will ultimately received water service commensurate with its needs.

In the determination of ultimate land use, certain assumptions were made as to the ultimate disposition of lands presently within military reservations. Military bases in and adjacent to metropolitan areas which are now occupied by predominately urban types of land use were assumed to remain intact, and the land use was tabulated with the gross urban area. Irrigable lands within military reservations in other areas were included with the tabulations of total irrigable area, and any lands suitable for urbanization were included with the gross urban area.

Irrigated Lands

It was assumed that ultimately all lands in the South Coastal Area that are suitable for irrigated agriculture, and not then occupied by urban and suburban developments, would be irrigated. This gross irrigable area was estimated, with the aid of data from the land classification surveys, to be about 1,156,000 acres, after deductions were made for otherwise irrigable lands assumed to be ultimately urbanized. An estimated 36,000 acres of the gross area represent lands expected to be occupied by farm lots, and an additional 96,000 acres represent the included nonwater-using lands such as roads, railroads, nonirrigable lands, etc. The remaining 1,024,000 acres represent the average area estimated to be irrigated each year under ultimate conditions of development. Table 82 lists the estimates of ultimate irrigable areas in hydrographic units of the South Coastal Area, and Table 83 presents these data by counties.

It will be noted that in the Los Angeles, San Diego, and San Gabriel Mountains Hydrographic Units the net ultimate irrigated area is the same as the gross irrigable area. It is anticipated that in the two metropolitan areas the ultimate irrigated areas will probably consist of inclusions within predominately urbanized areas. Under these circumstances farm lots and the inclusions cited in the preceding paragraph will be a part of the urban area. In the San Gabriel Mountains Hydrographic Unit the forecast of ultimately irrigated lands was based upon estimates of the United States Forest Service, which indicated net irrigated areas only.

TABLE 82

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, SOUTH COASTAL AREA

(In acres)

Hydrographic unit		Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
Reference number	Name				
1	Ventura	5,600	300	600	4,700
2	Santa Clara-Calleguas	161,000	8,000	13,800	139,000
3	Malibu	3,000	200	300	2,500
4	San Gabriel Mountains	300	[a]		300
5	Upper Santa Ana	371,000	[a]	33,200	338,000
6	Los Angeles	50,300	[a]		50,300
7	San Juan Capistrano	91,100	4,700	8,100	78,300
8	Santa Margarita-San Luis Rey	222,000	11,200	19,900	191,000
9	San Dieguito-Cottonwood	230,000	11,400	20,500	198,000
10	San Diego	22,200	[a]		22,200
	APPROXIMATE TOTALS	1,156,000	35,800	96,400	1,024,000

[a] Included in "Urban and Suburban Area."

TABLE 83

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN COUNTIES, SOUTH COASTAL AREA

(In acres)

County	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
Los Angeles	82,700	2,100	3,900	76,700
Orange	61,600	2,500	4,300	54,800
Riverside	337,000	4,000	31,000	302,000
San Bernardino	110,000	[a]	9,100	101,000
San Diego	437,000	20,800	37,000	379,000
Ventura	128,000	6,400	11,100	111,000
APPROXIMATE TOTALS	1,156,000	35,800	96,400	1,024,000

[a] Included in "Urban and Suburban Area."

Urban Growth in San Diego
Metropolitan Area

From historical callection of Union Title Insurance and Trust Company, San Diego, California

To aid in estimating the probable ultimate water requirements, a crop pattern applicable to the probable ultimate net irrigated area was forecast. It is recognized that future developments may indicate that this crop pattern may be somewhat in error, both as to the portion of the probable ultimate irrigable area in the South Coastal Area devoted to each crop group, and as to the distribution of the area of each crop group between hydrographic units. However, it is felt that the magnitude of the ultimate water requirement would not be seriously affected. Table 84 presents this estimated crop pattern for the South Coastal Area.

Urban and Suburban Water Service Areas

It is considered probable that the present trend of rapid urbanization in certain portions of the South Coastal Area will continue in the future. In estimates for this bulletin, it was assumed that urban and suburban types of land use ultimately will occupy all lands in the Los Angeles and San Diego Hydrographic Units, except for scattered small agricultural areas and those lands topographically unsuited for development. Consideraton of present trends in Ventura County and in the Upper Santa Ana Valley indicates that large portions of these regions will ultimately be urban in character. It was assumed that this urbanization will take place almost entirely on lands classified as irrigable. With increasing population in the South Coastal Area, it is probable that there will be a proportionate increase in urban beach communities, such as those presently expanding along the southerly portion of the coast line of Orange County. It was assumed that in the future more of this type of development will take place along the coast line adjacent to the Santa Monica Mountains, and all along the coast between Los Angeles and San Diego.

It is probable that in the remainder of the South Coastal Area, urban and suburban development will, in general, be associated with agricultural pursuits, and it was assumed that such urban growth in the future will be proportional to increase in adjacent agricultural areas. Areas estimated to be ultimately occupied by the various urban land use types were determined by applying percentage factors to the determined ultimate gross urban and suburban area, the factors being based upon present urban land use patterns and expected future changes. As has been previously mentioned, estimates of the areas in military reservations occupied by urban types of land use are included in those of the gross urban area. In the determination of probable ultimate water service areas, the area occupied by farm lots was included as a portion of the gross irrigable area. Therefore, the estimate of probable ultimate gross urban and suburban water service area does not, as was the case in the present land use pattern, include farm lots.

Table 85 presents the probable ultimate pattern of land use in urban and suburban water service areas in hydrographic units, and Table 86 presents estimated probable ultimate gross urban and suburban areas in counties of the South Coastal Area.

Other Water Service Areas

The remaining 4,228,000 acres of the South Coastal Area, not included in either the ultimate irrigated or urban and suburban water service areas, were not classified in detail regarding the nature of their probable ultimate water service. It was assumed that these "other water service areas" will be ultimately served with water commensurate with their needs. Included in "other water service areas" are developed areas within the national forest boundaries (except for irrigated lands, the areas of which are included in Tables 82, 83, and 84), state beaches and parks, and scattered recreational, residential, and industrial developments not included in the probable ultimate urban and suburban water service area. The

TABLE 84
PROBABLE ULTIMATE PATTERN OF IRRIGATED CROPS, SOUTH COASTAL AREA
(In acres)

Hydrographic unit		Alfalfa	Pasture	Orchard	Walnuts	Citrus and subtropical	Truck crops	Beans	Hay and grain	Miscellaneous crops	Approximate total
Reference number	Name										
1	Ventura	------	800	700	900	2,300	------	------	------	------	4,700
2	Santa Clara-Calleguas	9,600	10,000	1,000	16,900	47,800	15,900	20,700	200	16,900	139,000
3	Malibu	100	800	------	100	200	1,300	------	------	------	2,500
4	San Gabriel Mountains	0	0	100	0	0	200	0	0	0	300
5	Upper Santa Ana	31,100	47,300	30,500	23,500	105,000	67,200	0	28,100	4,700	338,000
6	Los Angeles	6,700	5,700	800	2,500	23,600	6,600	2,000	300	2,100	50,300
7	San Juan Capistrano	3,500	9,000	2,700	300	32,500	16,000	10,400	900	3,000	78,300
8	Santa Margarita-San Luis Rey	3,200	36,100	8,900	2,900	36,500	37,800	17,100	37,700	11,200	191,000
9	San Dieguito-Cottonwood	4,200	35,000	14,800	5,700	67,700	39,900	22,400	1,400	6,600	198,000
10	San Diego	1,700	1,900	400	200	9,100	8,100	300	------	500	22,200
	APPROXIMATE TOTALS	60,100	146,000	59,900	53,000	325,000	193,000	72,900	68,600	45,000	1,024,000

TABLE 85

PROBABLE ULTIMATE URBAN AND SUBURBAN AREAS WITHIN HYDROGRAPHIC UNITS, SOUTH COASTAL AREA

(In acres)

Hydrographic unit		Area requiring water service					Area not requiring water service	Approximate gross area
Reference number	Name	Residential	Commercial	Industrial	Miscellaneous	Subtotal		
1	Ventura	11,800	1,100	600	800	14,300	6,200	20,500
2	Santa Clara-Calleguas	49,500	4,800	5,000	4,400	63,700	24,700	88,400
3	Malibu	14,000	1,100	0	500	15,600	7,200	22,800
4	San Gabriel Mountains							
5	Upper Santa Ana	131,000	8,600	13,700	7,400	161,000	73,300	234,000
6	Los Angeles	443,500	61,200	74,700	119,000	698,000	255,000	953,000
7	San Juan Capistrano	17,600	1,500	0	700	19,800	8,200	28,000
8	Santa Margarita-San Luis Rey	22,200	2,000	0	1,000	25,200	9,500	34,700
9	San Dieguito-Cottonwood	17,200	1,600	0	800	19,600	6,900	26,500
10	San Diego	97,200	9,600	1,900	21,800	131,000	72,200	203,000
	APPROXIMATE TOTALS	804,000	91,500	95,900	156,000	1,148,000	463,000	1,611,000

TABLE 86

PROBABLE ULTIMATE URBAN AND SUBURBAN AREAS WITHIN COUNTIES, SOUTH COASTAL AREA

(In acres)

County	Gross area
Los Angeles	726,000
Orange	271,000
Riverside	89,800
San Bernardino	147,000
San Diego	269,000
Ventura	108,000
APPROXIMATE TOTAL	1,611,000

greatest portion of these lands are in areas topographically or otherwise unsuitable for intensive development. As shown in Table 87, "other water service areas" were divided for convenience in estimating water utilization into those portions inside and outside of national forests, and above and below elevation 3,000 feet.

Summary

Table 88 presents a summary of probable ultimate water service areas, segregated into irrigated, urban and suburban, and other water service areas.

UNIT VALUES OF WATER USE

Unit seasonal values of water use in the South Coastal Area were determined in accordance with the methods and procedures described in Chapter II. Unit values of urban water use were based upon special studies conducted in the Los Angeles and San Diego Hydrographic Units. Data employed in determination of unit values of water use for irrigated crops included the results of studies conducted by various public agencies and records of water delivery supplied by numerous water service agencies.

TABLE 87

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, SOUTH COASTAL AREA

(In acres)

Hydrographic unit		Inside national forests, monuments, and military reservations		Outside national forests, monuments, and military reservations		Approximate total
Reference number	Name	Above 3,000-foot elevation	Below 3,000-foot elevation	Above 3,000-foot elevation	Below 3,000-foot elevation	
1	Ventura	40,700	41,200	0	59,700	142,000
2	Santa Clara-Calleguas	457,000	181,000	52,600	346,000	1,037,000
3	Malibu	0	0	400	111,000	111,000
4	San Gabriel Mountains	212,000	95,300	0	0	307,000
5	Upper Santa Ana	419,000	76,000	33,700	316,000	845,000
6	Los Angeles	8,100	20,800	1,000	153,000	183,000
7	San Juan Capistrano	13,200	75,200	0	115,000	203,000
8	Santa Margarita-San Luis Rey	91,400	21,400	131,000	348,000	592,000
9	San Dieguito-Cottonwood	155,000	127,000	95,500	339,000	716,000
10	San Diego	0	0	0	91,600	91,600
	APPROXIMATE TOTALS	1,397,000	638,000	314,000	1,879,000	4,228,000

TABLE 88

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS, SOUTH COASTAL AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigable lands	Urban and suburban areas	Other water service areas	Approximate total
1	Ventura	5,600	20,500	142,000	168,000
2	Santa Clara-Calleguas	161,000	88,400	1,037,000	1,286,000
3	Malibu	3,000	22,800	111,000	137,000
4	San Gabriel Mountains	300	----------	307,000	307,000
5	Upper Santa Ana	371,000	234,000	845,000	1,450,000
6	Los Angeles	50,300	953,000	183,000	1,186,000
7	San Juan Capistrano	91,100	28,000	203,000	322,000
8	Santa Margarita-San Luis Rey	222,000	34,700	592,000	849,000
9	San Dieguito-Cottonwood	230,000	26,500	716,000	973,000
10	San Diego	22,200	203,000	91,600	317,000
	APPROXIMATE TOTALS	1,156,000	1,611,000	4,228,000	6,995,000

Irrigation Water Use

Unit seasonal values of consumptive use of water by irrigated crops were in general determined in accordance with the methods of Chapter II. In certain cases, it was necessary to take into account the practice of raising more than one crop on the same land in a given year.

Except for Malibu, San Gabriel Mountains, and Upper Santa Ana, the hydrographic units were subdivided into coastal and interior isoclimatic zones, in order to account for variations in consumptive use of water. Estimated unit seasonal values of consumptive use of applied irrigation water and of precipitation by various crop groups are presented in Table 89.

In the determination of the probable ultimate water requirement on farm lots, unit seasonal values of water use were assumed to be the same as the unit values determined for rural residence in Tables 90 and 91.

Urban and Suburban Water Use

In all hydrographic units except San Diego, the estimates of present unit seasonal values of consumptive use of water on urban and suburban land use classifications were based upon estimates of consumptive use on the percentage of the area of each classification occupied by impervious areas, bare lands, lawns, shrubs, etc., and upon estimates of other urban consumptive uses, such as household use, air conditioning, etc. It was assumed that these present unit values would remain unchanged ultimately. In the San Diego Hydrographic Unit, urban and suburban water requirements were estimated on the basis of total water delivery, and unit values of consumptive use of applied water were not estimated for individual urban and suburban land use classifications.

TABLE 89

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, SOUTH COASTAL AREA

(In feet of depth)

Hydrographic unit		Alfalfa			Pasture			Orchard			Walnuts			Citrus and subtropical		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Ventura															
	Coastal	2.1	1.1	3.2	2.1	1.1	3.2	1.3	1.3	2.6	1.6	1.1	2.7	1.3	0.9	2.2
	Interior	2.5	1.1	3.6	2.5	1.1	3.6	1.5	1.2	2.7	1.6	1.3	2.9	1.6	0.9	2.5
2	Santa Clara-Calleguas															
	Coastal	2.1	1.1	3.2	2.1	1.1	3.2	1.3	1.3	2.6	1.6	1.1	2.7	1.3	0.9	2.2
	Interior	2.4	1.1	3.5	2.3	1.1	3.4	1.5	1.2	2.7	1.7	1.1	2.8	1.4	1.0	2.4
3	Malibu	2.0	1.3	3.3	2.1	1.2	3.3	-----	-----	-----	1.5	1.3	2.8	1.2	1.1	2.3
4	San Gabriel Mountains	-----	-----	-----	-----	-----	-----	1.4	1.4	2.8	-----	-----	-----	-----	-----	-----
5	Upper Santa Ana	2.5	1.2	3.7	2.5	1.2	3.7	1.6	1.2	2.8	1.8	1.2	3.0	1.5	1.1	2.6
6	Los Angeles															
	Coastal	2.4	1.1	3.5	2.4	1.1	3.5	1.6	1.1	2.7	1.8	1.1	2.9	1.3	1.1	2.4
	Interior	2.3	1.3	3.6	2.5	1.1	3.6	1.5	1.3	2.8	1.6	1.3	2.9	1.4	1.2	2.6
7	San Juan Capistrano															
	Coastal	2.2	1.2	3.4	2.3	1.1	3.4	1.5	1.2	2.7	1.7	1.2	2.9	1.2	1.1	2.3
	Interior	2.4	1.2	3.6	2.5	1.1	3.6	1.5	1.2	2.7	1.7	1.2	2.9	1.4	1.1	2.5
8	Santa Margarita-San Luis Rey															
	Coastal	2.3	1.0	3.3	2.3	1.0	3.3	1.6	1.0	2.6	1.8	1.0	2.8	1.3	1.0	2.3
	Interior	2.1	1.4	3.5	2.3	1.2	3.5	1.4	1.3	2.7	1.6	1.2	2.8	1.3	1.2	2.5
9	San Dieguito-Cottonwood															
	Coastal	2.1	1.2	3.3	2.2	1.1	3.3	1.5	1.2	2.7	1.6	1.2	2.8	1.2	1.1	2.3
	Interior	2.2	1.4	3.6	2.4	1.2	3.6	1.5	1.2	2.7	1.6	1.3	2.9	1.3	1.2	2.5
10	San Diego															
	Coastal	2.4	0.9	3.3	2.4	0.9	3.3	1.8	0.8	2.6	1.9	0.9	2.8	1.4	0.9	2.3
	Interior	2.5	1.0	3.5	2.5	1.0	3.5	1.6	1.1	2.7	1.8	1.1	2.9	1.5	1.0	2.5

TABLE 89—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, SOUTH COASTAL AREA

(In feet of depth)

Hydrographic unit		Truck crops			Beans			Hay and grain			Miscellaneous crops		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Ventura												
	Coastal	1.0	1.1	2.1	----	----	----	----	----	----	----	----	----
	Interior	1.2	1.0	2.2	----	----	----	----	----	----	----	----	----
2	Santa Clara-Calleguas												
	Coastal	1.0	1.1	2.1	1.1	1.0	2.1	0.6	0.9	1.5	----	----	----
	Interior	1.1	1.0	2.1	1.1	1.1	2.2	0.7	0.9	1.6	1.1	1.0	2.1
3	Malibu	1.0	1.1	2.1	----	----	----	----	----	----	----	----	----
4	San Gabriel Mountains	1.2	1.0	2.2	----	----	----	----	----	----	----	----	----
5	Upper Santa Ana	1.3	0.8	2.1	----	----	----	0.7	1.0	1.7	1.3	0.8	2.1
6	Los Angeles												
	Coastal	1.3	0.9	2.2	1.3	0.9	2.2	0.7	0.9	1.6	1.3	0.9	2.2
	Interior	1.2	0.9	2.1	----	----	----	0.7	1.0	1.7	1.2	0.9	2.1
7	San Juan Capistrano												
	Coastal	1.2	0.9	2.1	1.2	0.8	2.0	----	----	----	1.3	0.8	2.1
	Interior	1.4	0.7	2.1	1.3	0.7	2.0	0.4	1.2	1.6	1.3	0.8	2.1
8	Santa Margarita-San Luis Rey												
	Coastal	1.3	0.8	2.1	1.2	0.7	1.9	0.5	1.0	1.5	1.4	0.6	2.0
	Interior	1.2	0.8	2.0	1.2	0.8	2.0	0.4	1.1	1.5	1.2	0.8	2.0
9	San Dieguito-Cottonwood												
	Coastal	1.2	0.9	2.1	1.2	0.8	2.0	0.3	1.2	1.5	1.4	0.6	2.0
	Interior	1.3	0.8	2.1	1.2	0.8	2.0	0.2	1.4	1.6	1.2	1.1	2.3
10	San Diego												
	Coastal	1.4	0.7	2.1	1.3	0.7	2.0	----	----	----	1.4	0.6	2.0
	Interior	1.4	0.7	2.1	1.3	0.7	2.0	----	----	----	1.5	0.6	2.1

Present unit values of net delivery of water to urban and suburban types of land use classification were based upon field surveys made in the Los Angeles and San Diego Hydrographic Units. In accordance with the methods described in Chapter II, total water deliveries to known areas occupied by the various classifications were determined, and unit values of delivery of water were derived from these data. In the determination of ultimate unit values of delivery of water, present unit values were modified somewhat in certain of the classifications to account for trends tending to alter the present values.

Table 90 presents unit seasonal values of consumptive use of water on, and net delivery to, land use classifications in the Los Angeles Hydrographic Unit. Table 91 lists estimated net delivery of water to various classifications used in the San Diego Metropolitan Area survey.

Tables 90 and 91 indicate that the present seasonal delivery of water to downtown types of commercial areas in Los Angeles is 10.2 feet of depth, and that it is 28.6 feet in San Diego. The difference is due to the fact that in the downtown type of commercial area in San Diego the development consists almost entirely of large buildings with relatively high water use, while in Los Angeles, one- and two-story buildings with a comparatively low water use represent a proportionately large part of the area.

Weighted mean unit values of seasonal delivery and consumptive use of water applicable to gross urban and suburban water service areas within hydrographic units, for both present and probable ultimate conditions of development, are presented in Table 92. Weighted mean unit values of consumptive use of water in the San Diego Hydrographic Unit were estimated from the relationship of consumptive use and delivery in the Los Angeles Metropolitan Area.

TABLE 90

ESTIMATED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY AND CONSUMPTIVE USE OF WATER ON URBAN AND SUBURBAN LAND USE CLASSIFICATIONS, LOS ANGELES HYDROGRAPHIC UNIT

(In feet of depth)

Land use classification	Delivery		Consumptive use of applied water
	Present	Ultimate	
Residential, single	2.6	2.8	1.3
Residential, multiple	4.5	5.0	0.3
Residential, estate	2.0	2.2	1.5
Residential, rural	1.8	1.8	0.8
Commercial, strip	3.4	4.0	0.4
Commercial, downtown	10.2	11.0	1.1
Industrial, manufacturing	9.2	8.5	1.4
Schools	0.9	1.1	0.4
Dairies	1.9	1.9	1.0
Livestock and poultry ranches	1.3	1.3	0.6
Oil fields	0.0	0.0	0.0
Subdivided, not occupied	0.0	0.0	0.0
Vacant	0.0	0.0	0.0
Airports	0.0	0.0	0.0
Streets and roads	0.0	0.0	0.0

TABLE 91

ESTIMATED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY TO URBAN AND SUBURBAN LAND USE CLASSIFICATIONS, SAN DIEGO HYDROGRAPHIC UNIT

(In feet of depth)

Land use classification	Unit delivery
Residential, single, with lawns	2.4
Residential, single, without lawns	2.5
Public housing, single story	3.4
Public housing, multiple story	6.2
Residential, multiple	7.4
Residential, rural	2.2
Commercial, strip	3.7
Commercial, downtown	28.6
Industrial, manufacturing	11.8
Schools	1.8
Institutions	1.8
Dairies	1.1
Livestock and poultry ranches	0.6
Parks, etc., with lawns	1.1
Parks, etc., without lawns	0.0
Vacant	0.0
Airports	0.0
Streets and roads	0.0

Table 92 indicates that probable ultimate mean unit values of urban water use will be significantly larger than the corresponding present unit values. This results largely from the assumption that the percentage of the gross urban area occupied by lands not requiring water service will decrease under ultimate conditions of development, due to occupancy of lands now vacant.

The difference between the ultimate mean unit urban delivery values for the Los Angeles Hydrographic Unit and the corresponding value for the San Diego Hydrographic Unit is primarily due to the relatively smaller industrial area in the San Diego Metropolitan Area. It was assumed that future growth in San Diego will be similar to that which has taken place to the present time, and that industrial areas will continue to occupy a relatively small percentage of the gross urban area.

TABLE 92

ESTIMATED WEIGHTED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY AND CONSUMPTIVE USE OF WATER ON GROSS URBAN AND SUBURBAN AREAS, SOUTH COASTAL AREA

(In feet of depth)

Hydrographic unit		Present		Probable ultimate	
Reference number	Name	Delivery	Consumptive use of applied water	Delivery	Consumptive use of applied water
1	Ventura	1.0	0.4	2.2	0.8
2	Santa Clara-Calleguas	1.2	0.4	2.5	0.8
3	Malibu	1.2	0.5	2.0	0.8
4	San Gabriel Mountains	----	----	----	----
5	Upper Santa Ana	1.9	0.7	2.4	0.8
6	Los Angeles	2.0	0.6	2.8	0.8
7	San Juan Capistrano	1.4	0.8	2.1	0.8
8	Santa Margarita-San Luis Rey	1.9	0.7	2.1	0.8
9	San Dieguito-Cottonwood	1.0	0.6	2.1	0.8
10	San Diego	1.8	0.6	2.0	0.6
	Weighted averages, South Coastal Area	1.9	0.6	2.5	0.8

Use of Water in Other Water Service Areas

Unit values of water use on lands requiring water service, but not included in the irrigated or urban and suburban water service areas, were derived generally from measured or estimated present deliveries of water to typical areas involved, or from records and estimates of per capita use of water. Since the quantity of water involved is small, and generally the recovery of return flow is negligible, total deliveries were considered to be consumptively used.

Unit values of water use within national forest boundaries were estimated by the United States Forest Service for both present and probable ultimate conditions of development. These estimates were generally in terms of per capita use of water, and were based on actual measurements and experience.

Unit values of probable ultimate water use on scattered residential, industrial, and recreational developments were determined on the basis of estimated population densities varying from 4 to 40 persons per square mile, and a per capita water use of 70 gallons per day. Water use in areas above an elevation of 3,000 feet was assumed to occur during the three summer months, while below an elevation of 3,000 feet, the water service was assumed throughout the year.

CONSUMPTIVE USE OF WATER

Consumptive use of water in water service areas of the South Coastal Area was generally determined by applying appropriate unit seasonal values of consumptive use of water to estimated areas occupied by crops of the various groups or to the urban and suburban classes of land use. Estimates of seasonal consumptive use of applied water and precipitation in present water service areas are given in Table 93. Table 94 presents corresponding estimates for probable ultimate conditions of development. These values represent the seasonal value of consumptive use of water under mean conditions of water supply and climate. In some hydrographic units of the South Coastal Area, actual present consumptive use of water is somewhat less than the optimum values from Table 93, due to existing deficiencies in water supply in portions of those hydrographic units.

TABLE 93

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, SOUTH COASTAL AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Urban and sub-urban areas	Un-classi-fied areas	Approx-imate total con-sump-tive use of applied water
Refer-ence number	Name	Applied water	Precipi-tation	Applied water	Applied water	
1	Ventura	6,400	3,900	3,200	100	9,700
2	Santa Clara-Calleguas	157,000	116,000	8,800	200	166,000
3	Malibu	1,400	1,100	700		2,100
4	San Gabriel Mountains	400	300		200	600
5	Upper Santa Ana	299,000	201,000	42,600	1,400	343,000
6	Los Angeles	355,000	253,000	250,000	100	605,000
7	San Juan Capistrano	7,900	6,000	1,900		9,800
8	Santa Margarita-San Luis Rey	31,100	24,900	3,200	100	34,400
9	San Dieguito-Cottonwood	29,800	24,100	2,500	300	32,600
10	San Diego	31,000	16,500	24,800		55,800
	APPROXIMATE TOTALS	919,000	647,000	338,000	2,400	1,259,000

FACTORS OF WATER DEMAND

In the planning of water conservation projects and accompanying distribution systems, certain factors in addition to consumptive use of water must be given consideration. Among these factors are necessary rates, times, and places of delivery of water, quality of water, losses of water, soil conditions, and other pertinent considerations. The most important of these factors in the South Coastal Area are those relating to the monthly distribution of water demands and the effciency of water utilization. These demand factors are briefly discussed in the following sections.

Monthly Distribution of Water Demands

Monthly demand for irrigation water may vary from little or none during the winter months to more than 15 per cent of the seasonal total during a dry summer month. The monthly distribution of seasonal water demand varies with the crop, soil type, and distance from the coast. Urban water demands are substantially higher during the summer months, but exhibit greater uniformity throughout the season than those for irrigation. Table 95 presents estimates of the average monthly distribution of seasonal water demands for urban lands and for irrigated agriculture in the South Coastal Area. The values for urban demands are based on delivery records of the Los Angeles Department of Water and Power during the period from 1944 through 1951. The values for irrigation demands are based on records of several water service agencies throughout the area, and are indicative of current practice.

Water Service Area Efficiency

Determination of seasonal water requirements in the South Coastal Area involved evaluation of the consumptive use of applied water, and also the unavoidable and irrecoverable losses incurred in the conveyance and utilization of the water. Water requirements in the South Coastal Area were determined from consideration of total water application in each hydrographic unit, consumptive use of applied water, irrigation efficiency, subsequent re-use of a portion of the applied water, losses associated with conveyance of water to places of use, and the final loss by discharge to the ocean. The effect of irrecoverable losses upon the water requirement may be measured by the

TABLE 94

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, SOUTH COASTAL AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Other water service areas	Approximate total consumptive use of applied water
Refer-ence number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
1	Ventura	8,500	5,000	200	16,400	500	25,600
2	Santa Clara-Calleguas	205,000	144,000	6,400	73,900	2,700	288,000
3	Malibu	3,700	3,000	200	17,900	400	22,200
4	San Gabriel Mountains	400	300			900	1,300
5	Upper Santa Ana	563,000	352,000		187,000	4,500	755,000
6	Los Angeles	80,800	54,100		770,000	1,300	852,000
7	San Juan Capistrano	121,000	75,400	3,800	22,800	1,000	149,000
8	Santa Margarita-San Luis Rey	251,000	201,000	8,900	29,100	1,700	291,000
9	San Dieguito-Cottonwood	300,000	212,000	9,100	22,700	2,600	334,000
10	San Diego	34,900	18,800		124,000	400	159,000
	APPROXIMATE TOTALS	1,568,000	1,065,000	28,600	1,264,000	16,000	2,877,000

TABLE 95

DISTRIBUTION OF MONTHLY WATER DEMANDS, SOUTH COASTAL AREA

(In per cent of seasonal total)

Month	Irrigation demand	Urban demand
January	2.7	6.4
February	2.2	6.4
March	3.8	7.0
April	6.5	8.0
May	10.9	9.1
June	12.8	9.8
July	13.7	10.8
August	13.6	10.6
September	12.5	9.6
October	9.5	8.4
November	7.2	7.3
December	4.6	6.6
TOTALS	100.0	100.0

water service area efficiency, defined as the ratio of consumptive use of applied water in a service area to the gross amount of water delivered in the area. Water service area efficiencies were estimated for each hydrographic unit of the South Coastal Area, after consideration of both irrigated and urban and suburban lands therein.

Irrigation efficiency is defined as the ratio of consumptive use of applied water to the total amount of water applied to irrigated crops. In the South Coastal Area there are significant variations in irrigation efficiency, dependent upon crop, soil type, topographic characteristics, cost and availability of water, and local irrigation practice. Generally throughout the area, irrigation efficiencies average about 70 per cent. The relatively high efficiency is principally attributed to existing water deficiencies and the high cost of water supplies in some portions of the area. Comparison of the total pumpage of ground water for irrigated lands on the coastal plain of Ventura County with the estimated total consumptive use of applied water on these lands, for the period from 1944-45 through 1951-52, provided further substantiation for the derived values for average irrigation efficiency.

Table 96 presents the estimated water service area efficiencies under present and probable ultimate conditions of development. Predictions of ultimate water service area efficiencies are obviously subject to material change, and such efficiencies will be dependent in great part on ultimate plans for water service, and the extent to which return flow from irrigated lands and urban areas can be regulated and re-used.

WATER REQUIREMENTS

Water requirements, as the term is used in this bulletin, refer to the amounts of water needed to provide for all beneficial uses of water and for any irrecoverable losses incidental to such uses. Certain requirements for water which are basically nonconsumptive in nature are discussed briefly in the following section in general terms. Following this, water requirements of a consumptive nature are evaluated for both present and probable ultimate conditions of development.

Requirements of a Nonconsumptive Nature

The principal nonconsumptive water requirements of the South Coastal Area are those pertaining to preservation and propagation of fish and wildlife, flood control, repulsion of sea water from ground water basins, and salt balance in irrigated areas. This bulletin does not evaluate the quantities of water involved in satisfying these requirements, since the quantities in many instances are dependent upon the evolution of definite plans for development of water resources. Their consideration herein is limited to discussion of their implications as related to planning for future water resource development.

TABLE 96

ESTIMATED WEIGHTED MEAN WATER SERVICE AREA EFFICIENCY WITHIN HYDROGRAPHIC UNITS, SOUTH COASTAL AREA

(In per cent)

Hydrographic unit		Present			Probable ultimate		
Reference number	Name	Irrigated	Urban and suburban	Weighted mean	Irrigated	Urban and suburban	Weighted mean
1	Ventura	90	55	75	100	55	65
2	Santa Clara-Calleguas	95	50	90	80	45	65
3	Malibu	90	50	70	80	50	55
4	San Gabriel Mountains	--	--	--	--	--	--
5	Upper Santa Ana	100	90	95	95	70	90
6	Los Angeles	85	35	55	80	30	30
7	San Juan Capistrano	75	50	70	80	40	70
8	Santa Margarita-San Luis Rey	95	45	90	80	50	75
9	San Dieguito-Cottonwood	80	55	75	80	55	75
10	San Diego	65	30	40	65	30	35
	Weighted averages, South Coastal Area	90	40	65	85	35	50

Navigation, although a factor in the water problems in some other portions of the State, is not a consideration in the water resource development of the South Coastal Area. Similarly, there is but negligible generation of hydroelectric power in the South Coastal Area. The present installed power capacity of hydroelectric power plants utilizing local water supplies is less than 15,000 kilowatts. Additionally, hydroelectric power plants in the South Coastal Area, operated in conjunction with the Los Angeles Aqueduct from the Owens River, have an installed power capacity of about 100,000 kilowatts. The limited and erratic occurrence of runoff in streams of the South Coastal Area makes it improbable that there will be any significant future increase in hydroelectric power generation.

Fish and Wildlife. Fresh-water fishing in the South Coastal Area is characterized by many anglers and limited fishing waters. The waters that are present, however, are utilized to their maximum capacity.

Practically all of the headwater streams, lakes, and reservoirs are planted regularly with catchable trout by the California Department of Fish and Game. It is in this area that the catchable trout program has reached its greatest development, with angling pressures so great that the majority of the planted trout are caught. During the 1954 trout angling season approximately 1,500,000 catchable-size trout were planted here, and it is estimated that at least two-thirds of them were caught.

Reservoirs located at low and moderate elevations in the South Coastal Area support excellent populations of warm-water game fish. Favorable climatic conditions and heavy angling pressures contribute to high yields from these reservoirs. Angling catch estimates for 1953, based on post card surveys by the Department of Fish and Game, show the following catches of warm-water fish in this region:

Species	*Number caught in South Coastal Area*	*Per cent of State total*
Black bass	510,000	22
Catfish	450,000	6
Crappie	1,430,000	40
Sunfish	1,760,000	28

The municipal water supply reservoirs owned by the City of San Diego are examples of those supporting successful warm-water fisheries in this area. Numerous farm ponds also provide warm-water fishing.

Several streams in the South Coastal Area, such as the Ventura and Santa Clara Rivers, and, to a lesser degree, Malibu and San Juan Creeks, support minor runs of steelhead trout when sufficient flow is available in the streams. Sufficient water is seldom available, however, and this fishery is only of minor value.

It is considered doubtful that the limited water resources of the South Coastal Area can meet additional water requirements for the preservation and enhancement of fish life, except when such requirements do not decrease supplies available to meet requirements of a consumptive nature. This does not, however, signify that fisheries will not benefit by future water development, particularly by importation of water from outside sources. Reservoirs created to impound water will provide additional habitat for game fish populations. Water released in stream beds for downstream requirements will, if the water is drawn from the deeper parts of the reservoir, provide conditions suitable for the development of trout fisheries. It is necessary only to provide minimum pool elevations in the reservoirs, and assure public access to the created waters, to realize fisheries benefits from water development in the South Coastal Area.

Water requirements for game species in this area are estimated to be less than 0.5 acre-foot per day. Development of water for this purpose has consisted of the installation of "gallinaceous guzzlers" (self-sustaining watering devices) primarily for upland game species. Future water development for game species is expected to be along similar lines.

Flood Control. Many projects designed to protect property adjacent to stream channels from damage by flood flows have been constructed in the densely developed portions of the South Coastal Area, and particularly in the Los Angeles Metropolitan Area. Large reservoirs, including Lopez, Sepulveda, and Hansen on the Los Angeles River and tributaries; San Gabriel No. 1, San Gabriel No. 2, Santa Fe, and Whittier Narrows on the San Gabriel River and tributaries; and San Antonio, Prado, and others on the Santa Ana River and tributaries, have been, or are being constructed to impound flood flows for later release. Many miles of channel in the Los Angeles River and San Gabriel River systems have been lined with impervious materials. Levees have been constructed along the San Gabriel and Santa Ana Rivers, and to a lesser degree along the Ventura and San Diego Rivers. Many debris basins have been constructed, principally on tributaries of the Los Angeles and San Gabriel Rivers. Extensive storm drain systems have been constructed to carry off valley floor runoff from intensively urbanized areas.

The Corps of Engineers, United States Army, in cooperation with local agencies, is engaged in a continuing program of planning and construction for flood protection in the South Coastal Area. In 1952 the people of Los Angeles County provided $179,000,000 for expenditure by the Los Angeles County Flood Control District in the construction of additional storm drain facilities for protection of urban areas.

Alteration of the natural regimen of streams and channels in the South Coastal Area has significantly affected the recharge of ground water basins. The operation of reservoirs for flood control purposes involves the temporary storage of flood flows and subsequent rapid release. Many of the channels and outflow areas from which water previously percolated have been paved or otherwise altered so as to expedite discharge of water to the ocean. Lands which formerly were flooded at frequent intervals have been improved for urban, industrial, and agricultural uses and provided with drains for rapid disposal of flood waters. Conservation of a portion of the flood waters which would otherwise be wasted is accomplished by construction and operation of spreading grounds for ponding of flood control reservoir releases. The Los Angeles County Flood Control District has operated spreading grounds for several years, and is now constructing additional water-spreading areas concurrently with the construction of flood protection works.

Subsurface Outflow From Ground Water Basins to Ocean. In the South Coastal Area several confined ground water basins adjacent to the coast have been experiencing deterioration in water quality by intrusion of sea water. This intrusion may be prevented by maintaining pressure levels in these basins at elevations such that subsurface outflow of fresh water will occur during periods of little or no pumping draft. Determination of the quantities of water required to prevent sea-water intrusion will be dependent upon specific plans of development and pumping draft. However, it appears that a substantial amount of water will be unavoidably lost by such outflow, particularly from the coastal plains of Ventura, Los Angeles, and Orange Counties. Studies conducted by the Division of Water Resources in Ventura County indicate that if pumpage from the presently overdrawn ground water basins underlying the coastal plain were limited to the safe yield of the basins, subsurface outflow to the ocean from these basins would be about 20,000 acre-feet per season.

The Los Angeles County Flood Control District is currently conducting a field experimental project in the Manhattan Beach-Hermosa Beach area to investigate the hydraulic feasibility of creating a pressure ridge in confined aquifers by means of injection wells, and the effectiveness of such a ridge in preventing sea-water intrusion. The project was initially financed from a state appropriation in the amount of $750,000, but since July 11, 1954, funds for this project have been furnished from a Flood Control District ad valorem zone tax.

Salt Balance. Local irrigation water supplies are, for the most part, obtained by pumping from ground water storage. The estimates of requirements for water of a consumptive nature, which are subsequently set forth, are predicated upon utilization of ground water storage capacity so as to facilitate the re-use of local and imported water applied to lands in excess of consumptive use. Natural replenishment of many ground water basins in the South Coastal Area is derived from surface drainage from tributary watersheds, and by subsurface outflow from upstream basins. The mineral quality of the ground water contained in these basins must be protected from excessive deterioration in order to maintain the utility of the storage capacity. This will require sufficient drainage from the basins to remove a quantity of dissolved salts equivalent to the amount of salt input to the basins. Quantitative estimates of the amount of water required for this purpose will necessarily depend upon the formulation of specific plans for future development in each instance.

Requirements of a Consumptive Nature

Requirements for water represent the quantities of water, other than precipitation, which must be supplied to provide for beneficial consumptive use of water on irrigated lands, urban and suburban areas, and other water service areas, and to provide for irrecoverable losses incidental to such use. Present and probable ultimate water requirements in the South Coastal Area were determined by use of the previously derived estimates of total water application and consumptive use of applied water, giving consideration to the possible re-use of a portion of the applied water and to losses incurred in conveyance to the place of use.

In general, in irrigation water service areas overlying or immediately adjacent to major free ground water basins, it was assumed that re-use of all water applied in excess of consumptive use could be accomplished. The water requirement for such areas was therefore taken as equal to the consumptive use of applied water plus any irrecoverable conveyance loss. In those irrigation water service areas adjacent to the coast or overlying confined aquifers, it was assumed that no re-use of applied water could be effected in excess of consumptive use. The water requirement in these cases was assumed to be equal to the total water applied plus irrecoverable conveyance losses. In inland areas overlying nonwater-bearing formations, or ground water basins of relatively small storage capacity in comparison with the potential water-using development, studies were made in order to estimate the portion of return flow from applied water that would be susceptible of re-use, and which would be irrecoverably lost. For such areas the water requirement was taken as the summation of consumptive use of applied water and irrecoverable losses

Urban and suburban water requirements were evaluated in the same general manner as those for irrigated lands, except that consideration was given to the effect on requirements in urban areas overlying free ground water basins of construction of sewerage facilities with ocean discharge. The present water requirement for these urban areas was estimated as the sum of consumptive use of applied water, present export to the ocean of sewage, and irrecoverable conveyance loss. The probable ultimate urban requirement in inland areas overlying free ground water basins was assumed to be the sum of consumptive use of applied water on the portion of the area without ocean discharge of sewage, total applied water on the portion of the area with such disposal, and irrecoverable conveyance losses. It was assumed that in the Los Angeles Hydrographic Unit, 85 per cent, and in the Santa Ana Hydrographic Unit, 20 per cent of the probable ultimate urban and suburban area overlying free ground water would use ocean disposal of sewage.

No consideration was given to reclamation and reuse of sewage which would otherwise be discharged to the ocean. Large quantities of water could be salvaged in this manner. Experimental projects to determine the feasibility of reclamation of sewage are presently being conducted in portions of the Los Angeles Hydrographic Unit. Sufficient data are not presently available to evaluate quantitatively the effect of such sewage reclamation, and exploitation of this potential source of water supply is considered as development of new water in this bulletin.

Table 97 presents estimated present and probable ultimate water requirements for each hydrographic unit of the South Coastal Area.

Ultimate urban and suburban water requirements in the Los Angeles and San Diego Metropolitan Areas were also independently estimated, on the basis of forecast ultimate population. This procedure involved determination of the areas ultimately susceptible of urban and suburban development, the ultimate population densities in these areas, and the ultimate per capita water requirement.

In the Los Angeles Hydrographic Unit the boundary of the area ultimately to be devoted to urban and suburban land uses was determined with reference to topographic suitability and residual agricultural development. The boundary as determined included an area of about 905,000 acres. The ultimate population density in this area was estimated to be about 13.6 persons per acre, based upon a detailed study of approximately the northern half of the Los Angeles County portion of the metropolitan area. This indicated an ultimate population for the entire hydrographic unit of about 12,300,000. The present use of water, based on available data in portions of the ultimate area, indicated that the ultimate per capita water requirement would be about 190 gallons per day. The ultimate urban and suburban seasonal water requirement was, on this basis, estimated to be about 2,600,000 acre-feet.

The San Diego Hydrographic Unit was subdivided, for purposes of analysis, into areas corresponding to census tracts or enumeration districts. Within each subdivision two topographical zones were delineated, one assumed to be ultimately fully developed and the other, of intermediate topography, assumed to be ultimately developed to one-half maximum density. The effective habitable area for each subdivision was assumed to be equivalent to the total area of the first zone plus one-half the area of the latter zone. Deductions from the effective habitable area were made for ultimate industrial areas and residual agriculture, prior to applying estimated population densities. Ultimate population densities applicable to the urban area, exclusive of industry, were estimated for each subdivision. The result of this analysis indicated that the total ultimate urban area (exclusive of industry) would be about 150,000 acres, and that the ultimate population would be about 1,990,000. Ultimate per capita water use in this hydrographic unit, including industrial use of water, was estimated to be about 160 gallons per day. The ultimate urban and suburban seasonal water requirement was, therefore, estimated to be about 360,000 acre-feet.

TABLE 97

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER, SOUTH COASTAL AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas		Other water service areas		Approximate totals	
Reference number	Name	Present	Probable ultimate	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate
1	Ventura	7,100	8,500	----------	5,800	29,800	100	500	13,000	38,800
2	Santa Clara-Calleguas	165,000	256,000	9,000	17,600	164,000	200	2,700	183,000	432,000
3	Malibu	1,600	4,600	----------	1,400	35,800	----------	400	3,000	40,800
4	San Gabriel Mountains	800	----------	----------	----------	----------	200	1,000	1,000	1,000
5	Upper Santa Ana	299,000	593,000	----------	47,300	267,000	1,400	4,500	348,000	864,000
6	Los Angeles	418,000	101,000	----------	716,000	2,568,000	100	1,300	1,134,000	2,670,000
7	San Juan Capistrano	10,500	151,000	6,000	3,800	57,000	----------	1,000	14,300	215,000
8	Santa Margarita-San Luis Rey	32,800	313,000	15,000	7,100	58,200	100	1,700	40,000	388,000
9	San Dieguito-Cottonwood	37,300	375,000	15,000	4,500	41,300	300	2,600	42,100	434,000
10	San Diego	47,700	53,700	----------	81,700	414,000	----------	400	129,000	468,000
	APPROXIMATE TOTALS	1,020,000	1,856,000	45,000	885,000	3,635,000	2,400	16,100	1,907,000	5,552,000

Supplemental Requirements

The supplemental water requirement, as the term is used in this bulletin, refers to the quantity of water, in addition to safe yield of the present water supply development, which must be made available to fully satisfy the present or probable ultimate water requirement. The present supplemental requirement represents the difference between the present water requirement and the sum of presently developed safe yield of local supplies and present import of water. The difference between estimated present and probable ultimate water requirements for each hydrographic unit, plus the present supplemental requirement, was taken as the measure of the probable ultimate supplemental water requirement.

The existence of a present supplemental requirement is indicative of one or more of several conditions. In certain portions of the South Coastal Area, irrigated crops are being supplied with amounts of water which are insufficient to provide for optimum consumptive use, with resultant decrease in crop yield and damage to plants. In San Diego County surface reservoirs have been operated in excess of safe yield, with the result that in the latter years of the recent drought period many of the reservoirs were dry. Except for the timely importation of Colorado River water, the San Diego Hydrographic Unit would be experiencing a water deficiency aggregating approximately 50 per cent of the present requirement for the unit. In the Santa Clara-Calleguas, Upper Santa Ana, and Los Angeles Hydrographic Units, and to a lesser extent in other units, extractions from ground water storage have exceeded safe yields of the underground reservoirs, resulting in appreciable overdrafts on existing supplies. Indications of possible ground water overdraft in the South Coastal Area include perennial lowering of ground water levels, sea-water intrusion, and dewatering of the ground water basins with limited storage capacity to the extent that overlying users are deprived of water supplies during drought periods.

Safe Yield of Local Water Supplies With Present Development. In connection with studies to determine values of presently developed safe seasonal local yield, use was made of data appearing in recent publications of the State Water Resources Board, the Division of Water Resources, and other organizations. Use was also made of unpublished data compiled in conjunction with the investigations currently being conducted by the Division of Water Resources. Values of safe yield presented in this bulletin in many instances must be considered as approximations, and only indicative of the general order of magnitude. In those areas where detailed data were not available and where water shortages are not presently apparent, safe yield of the present water supply development was assumed to be equal to the estimated present water requirement. Estimates of presently developed safe seasonal local yield in hydrographic units of the South Coastal Area are presented in Table 98.

TABLE 98

ESTIMATED PRESENTLY DEVELOPED SAFE SEASONAL YIELD OF LOCAL WATER SUPPLIES, SOUTH COASTAL AREA

(In acre-feet)

Hydrographic unit		Safe yield
Reference number	Name	
1	Ventura	9,000
2	Santa Clara-Calleguas	115,000
3	Malibu	3,000
4	San Gabriel Mountains	1,000
5	Upper Santa Ana	266,000
6	Los Angeles	509,000
7	San Juan Capistrano	13,000
8	Santa Margarita-San Luis Rey	29,000
9	San Dieguito-Cottonwood	34,000
10	San Diego	62,000
	TOTAL	1,041,000

Imported Water Supplies. The City of Los Angeles imports water from the Mono Basin and Owens River watersheds in the Lahontan Area through the Los Angeles Aqueduct. Such import of water supplements local supplies for only a portion the Los Angeles Metropolitan Area, as the City of Los Angeles restricts the delivery to the incorporated area of the city. During the 1949-50 season, the imported water supply was about 305,000 acre-feet. The capacity of the aqueduct is estimated by the Los Angeles Department of Water and Power to be about 320,000 acre-feet annually.

The Metropolitan Water District of Southern California imports supplemental water from Lake Havasu on the Colorado River through an aqueduct terminating at Lake Mathews in Riverside County. Cities and water districts forming the district are shown on Plate 13. Water is distributed by the Metropolitan Water District to all member cities and water districts except those in San Diego County. Colorado River water is supplied to San Diego County through an aqueduct which joins the the Colorado River Aqueduct near the City of San Jacinto and terminates in San Vicente Reservoir. From that point the water is distributed to member agencies by the San Diego County Water Authority. During the 1949-50 season about 166,000 acre-feet of water were distributed to member cities and water districts, and to the San Diego County Water Authority, by the Metropolitan Water District. This import had increased to 246,000 acre-feet during the 1953-54 season.

Table 99 presents estimates of water supplies imported to the South Coastal Area during the 1949-50 season.

In accordance with the 1931 Seven-Party Water Agreement, the Metropolitan Water District of Southern California, including the San Diego County Water Authority, is allotted 1,212,000 acre-feet per year of California's rights to water from the Colorado River. It has been estimated that due to conveyance losses the amount actually available for consumptive use in the South Coastal Area will be about 1,150,000 acre-feet per season. Thus a quantity of about 975,000 acre-feet of water from this source, over and above actual 1949-50 import, remains available to the area to assist in meeting the estimated ultimate water requirements. This amount of water, distributed among the areas requiring a present supply of supplemental water, would be more than adequate to eliminate the estimated present deficiencies.

Supplemental Water Requirements. Present and probable ultimate supplemental water requirements in the South Coastal Area were determined as the difference between water requirements, as presented in Table 97, and the sum of presently developed safe local yield and present import, as presented in Tables 98 and 99. Estimated supplemental water requirements for each hydrographic unit of the South Coastal Area are given in Table 100. In some cases the indicated supplemental water requirement for a given hydrographic unit is less than the sum of the supplemental requirements for small subdivisions of the unit, due to localized ground water overdrafts of relatively small magnitude. These local overdrafts could be eliminated with modification of the pattern of distribution of available water supplies within the unit.

TABLE 99

ESTIMATED PRESENT SEASONAL IMPORT, SOUTH COASTAL AREA

(In acre-feet)

Hydrographic unit		1949-50
Reference number	Name	
1	Ventura	0
2	Santa Clara-Calleguas	0
3	Malibu	0
4	San Gabriel Mountains	0
5	Upper Santa Ana	1,000
6	Los Angeles	399,000
7	San Juan Capistrano	2,000
8	Santa Margarita-San Luis Rey	3,000
9	San Dieguito-Cottonwood	0
10	San Diego	66,000
	TOTAL	471,000

TABLE 100

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS, SOUTH COASTAL AREA

(In acre-feet)

Hydrographic unit		Present	Probable ultimate
Reference number	Name		
1	Ventura	4,000	29,800
2	Santa Clara-Calleguas	68,000	317,000
3	Malibu	-	37,800
4	San Gabriel Mountains	0	0
5	Upper Santa Ana	81,000	597,000
6	Los Angeles	226,000	1,762,000
7	San Juan Capistrano	----	200,000
8	Santa Margarita-San Luis Rey	8,000	356,000
9	San Dieguito-Cottonwood	8,000	400,000
10	San Diego	0	340,000
	APPROXIMATE TOTALS	395,000	4,040,000

In order to satisfy estimated ultimate water requirements, about 4,040,000 acre-feet of water per season will be necessary, in addition to the presently available supplies. This requirement can only be met by further conservation of local supplies and by additional importation of water from sources of supply outside the South Coastal Area. About 975,000 acre-feet of the indicated ultimate seasonal supplemental requirement will be met when water supplies from the Colorado River available under existing rights are fully utilized.

CHAPTER VII

CENTRAL VALLEY AREA

The Central Valley Area comprises all of the stream basins tributary to the Sacramento and San Joaquin Rivers. It occupies about one-third of the total area of California, and contains sixty per cent of the State's irrigable land. This large area includes lands making up the westerly drainage of the Sierra Nevada and the Cascade Range, the easterly drainage of the Coast Range, and the floor of the great Central Valley between latitudes 35° and 42° N. It is approximately 500 miles in length and 120 miles in width. The Central Valley Area is designated Area 5 on Plate 8, and includes all or part of 39 of the State's 58 counties. Among the principal incorporated cities are Redding, Chico, Marysville, Sacramento, Stockton, Fresno, Modesto, Merced, Tulare, and Bakersfield.

In order to facilitate the present study, the Central Valley Area was subdivided into three principal basins: the Sacramento River Basin, where there is a surplus of water with only localized areas of deficiency; the San Joaquin River Basin, where for the most part the water supply balances the requirements under present conditions of development; and the Tulare Lake Basin, where the local water supply is insufficient to meet present requirements.

Each of the principal basins was further subdivided into hydrographic units, the boundaries of which are for the most part coincident with watershed divides of the tributary streams, or along water service area boundaries. The hydrographic units were generally segregated into two types, mountain and valley. Each mountain unit consists of the total drainage area of one or more tributary streams above the foothill line. There is usually a valley unit associated with each mountain unit. The mountain units were named with reference to streams in the tributary area, and names of the valley units correspond to principal towns or to geographical locations. Table 101 lists the 63 hydrographic units and their areas, and Table 102 presents the areas of counties, or portions of counties, included within the Central Valley Area.

The climate of the valley floor of the great Central Valley is characterized by hot summers and mild winters, light precipitation decreasing from north to south, and a summer and autumn period of nearly unbroken sunshine. The valley areas are free from frost during the normal growing season, from seven to eight months in length. Mean seasonal depth of precipitation at Red Bluff, at the northern end of the Central Valley floor, is approximately 20.3 inches, while at Bakersfield at the southerly extremity of the valley it is about 6 inches. At Modesto, approximately midway of the length of the valley, the mean seasonal precipitation depth is approximately 11 inches. Precipitation is extremely variable from year to year. At Sacramento, where an unbroken record has been maintained since 1849 and the average seasonal depth of rainfall is 18.08 inches, the maximum quantity recorded in any one season was 36.35 inches, and the minimum was 4.71 inches. Over 90 per cent of the rainfall in a typical year at Sacramento occurs during the six months from November through April, and only infrequent scattered showers occur during summer and fall.

The bordering mountains to the north and east of the Central Valley floor rise rapidly from the foothill line to an elevation of about 5,000 feet, above which a generally Alpine climate prevails, characterized by short summers, cold winters, and a frost-free period of only three months. The Cascade Range and the Sierra Nevada receive the greatest precipitation, with slightly less falling on the northern Coast Range. At elevations above 5,000 feet nearly all winter precipitation occurs as snow. Depth of snowfall in the Sierra Nevada is among the greatest experienced in the United States. Norden, at Donner Summit, which is a fairly representative station at an elevation of 6,871 feet, has a mean seasonal snowfall depth slightly greater than 400 inches, having a water content of approximately 50 inches. The snow accumulates during the winter and spring months, gradually melting so as to maintain stream flow into the warmer months of the summer.

It is estimated that mean seasonal natural runoff of streams in the Central Valley Area is about 33,640,000 acre-feet, about 48 per cent of that for the entire State. Approximately two-thirds of the runoff is provided by the Sacramento River and its tributaries, and the remainder by streams of the San Joaquin River and Tulare Lake Basins. Flow in streams of the Central Valley Area is dependent upon the extent of the drainage basins and upon the quantity and distribution of seasonal precipitation. Substantial winter rainfall in the Coast Range and the lower foothills of the Sierra Nevada causes immediate stream runoff. In the higher mountains the winter precipitation, which occurs as snow, usually remains on the ground until warmer temperatures in the spring and summer months induce melting of the snowpack. In general, the greatest volume of stream flow occurs in the spring and early summer, diminish-

Courtesy State Division of Highways

Mt. Shasta

TABLE 101

AREAS OF HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

Hydrographic unit: Reference number	Hydrographic unit: Name	Acres
	Sacramento River Basin	
	Mountain Units	
1	Goose Lake	264,000
2	Pit River	3,440,000
3	McCloud River	438,000
4	Sacramento River above Shasta Dam	396,000
5	West Side, Shasta Dam to Cottonwood Creek	815,000
6	East Side, Cow Creek to Paynes Creek	819,000
7	Red Bluff to Thomes Creek	536,000
8	Antelope to Mud Creek	529,000
9	Stony Creek	630,000
10	Butte and Chico Creeks	204,000
11	Cortina Creek	267,000
12	Feather River	2,395,000
13	Yuba and Bear Rivers	1,102,000
14	Cache Creek	732,000
15	American River	1,313,000
16	Putah Creek	405,000
	Subtotal, Mountain Units	14,280,000
	Valley Units	
17	Anderson-Cottonwood	37,800
18	Tehama	129,000
19	Vina	136,000
20	Orland	145,000
21	Chico	111,000
22	Arbuckle	126,000
23	Colusa Trough	579,000
24	Feather River to Butte Slough	341,000
25	Yuba	81,900
26	Marysville-Sheridan	217,000
27	Woodland	201,000
28	Carmichael	307,000
29	Dixon	217,000
30	Yolo	197,000
	Subtotal, Valley Units	2,826,000
	APPROXIMATE TOTAL, SACRAMENTO RIVER BASIN	17,110,000
	Tulare Lake Basin	
	Mountain Units	
31	West Side, Kern County	306,000
32	Kern River and Tehachapi Mountains	2,837,000
33	Tule River	466,000
34	Kaweah River	611,000
35	Kings River	1,186,000
	Subtotal, Mountain Units	5,406,000
	Valley Units	
36	Antelope Plain	701,000
37	Kern	1,161,000
38	Earlimart	434,000
39	Visalia	469,000
40	Fresno-Hanford	1,125,000
41	Tulare Lake	256,000
	Subtotal, Valley Units	4,146,000
	APPROXIMATE TOTAL, TULARE LAKE BASIN	9,552,000
	San Joaquin River Basin	
	Mountain Units	
42	Mount Diablo	102,000
43	Altamont to San Luis Creek	483,000
44	West Side, Los Banos Creek to Avenal Creek	863,000
45	San Joaquin River	1,117,000
46	Chowchilla-Fresno Rivers	417,000
47	Merced River	944,000
48	Tuolumne River	1,032,000
49	Stanislaus River	705,000
50	Mokelumne-Calaveras Rivers	734,000
51	Cosumnes River	489,000
	Subtotal, Mountain Units	6,886,000
	Valley Units	
52	Antioch	94,400
53	Delta-Mendota	74,500
54	West Side, San Joaquin Valley	793,000
55	Madera	484,000
56	Merced	523,000
57	Los Banos	413,000
58	Modesto	452,000
59	Vernalis	86,100
60	Oakdale	254,000
61	Stockton	574,000
62	Ione	272,000
63	Sacramento-San Joaquin Delta	481,000
	Subtotal, Valley Units	4,501,000
	APPROXIMATE TOTAL, SAN JOAQUIN RIVER BASIN	11,390,000
	APPROXIMATE TOTAL, CENTRAL VALLEY AREA	38,050,000

ing in amount to little or no flow during the final quarter of the season. Records of stream flow for the American River, which is generally representative of streams of the Sierra Nevada, show that over 65 per cent of the seasonal runoff occurs during the four-month period from March through June, and 93 per cent during the period from December through June. Total seasonal runoff varies from year to year in the same general pattern as precipitation. A 43-year record of flow in the American River at Fair Oaks shows that the seasonal runoff has varied from a low of 20 per cent of the average seasonal runoff in 1923-24, to a high of 216 per cent in 1906-07.

As shown on Plate 4, a total of 29 valley fill areas, which may or may not contain usable ground water, has been identified in the Central Valley Area, of which those of the Sacramento River, San Joaquin River, and Tulare Lake Basins are by far the most important, both in size and in the extent to which they have been developed. The estimated gross subsurface storage capacity of the Sacramento River Basin is estimated to be nearly 33,700,000 acre-feet in the depth zone between 20 and 200 feet. Very little of this storage capacity is presently utilized. About 1,000,000 acre-feet of water is pumped from ground water storage during the average season, which water constitutes about 25 per cent of the amount consumptively used in the Sacramento River Basin in the average season under present conditions of development.

TABLE 102

AREAS OF COUNTIES WITHIN BOUNDARIES OF CENTRAL VALLEY AREA

County	Acres
Alameda	52,500
Alpine	161,000
Amador	383,000
Butte	1,072,000
Calaveras	665,000
Colusa	740,000
Contra Costa	180,000
El Dorado	999,000
Fresno	3,843,000
Glenn	792,000
Kern	3,598,000
Kings	893,000
Lake	660,000
Lassen	911,000
Los Angeles	2,600
Madera	1,378,000
Mariposa	934,000
Merced	1,270,000
Modoc	1,513,000
Napa	220,000
Nevada	518,000
Placer	799,000
Plumas	1,670,000
Sacramento	638,000
San Benito	205,000
San Joaquin	911,000
San Luis Obispo	106,000
Shasta	2,468,000
Sierra	477,000
Siskiyou	698,000
Solano	342,000
Stanislaus	973,000
Sutter	390,000
Tehama	1,910,000
Tulare	3,102,000
Tuolumne	1,471,000
Ventura	30,000
Yolo	662,000
Yuba	412,000
APPROXIMATE TOTAL	38,050,000

The ground water basins of the San Joaquin River Basin and the Tulare Lake Basin, with estimated gross subsurface storage capacities in the depth zone between 20 and 200 feet of about 47,500,000 acre-feet and 51,400,000 acre-feet, respectively, provide seasonal and cyclic storage to regulate the water supplies of those basins. Ground waters on the east side of the Tulare Lake Basin have been developed to such an extent that in localized areas their rate of use on overlying lands exceeds the rate of ground water replenishment from stream flow and return drainage, resulting in overdrafts in local sub-basins. The local overdrafts are now being replenished to some extent by water from the Friant-Kern Canal.

In the San Joaquin River Basin, the eastern portion of the ground water basin south of the Sacramento-San Joaquin Delta is extensively utilized to provide a partial water supply, used in conjunction with surface diversions. Except in localized areas, the use of water from this portion of the basin does not exceed replenishment. Since about 1942 the western side of the San Joaquin Valley has experienced a phenomenal expansion in agricultural development, which has caused greatly increased demand on the ground water in storage. This demand far exceeds the replenishment. During a recent 5-year period, average ground water levels in the western side of the San Joaquin River Basin dropped at a rate of approximately 8 feet per year in the northern section, and 21 feet per year in the southern section. It is anticipated that ground water will continue to be utilized in this area in the future, but that an increasing proportion of the requirement for water will necessarily be met by imported surface water supplies.

During recent years the Central Valley Area has led all other major areas of the State in growth of population on a percentage basis. The expanding agricultural economy and related industrial growth brought an increase of population from 400,000 in 1900 to 1,900,000 in 1950, or some 375 per cent. Nearly all urban centers have grown correspondingly in size and importance, with growth in the surrounding suburban areas being particularly noticeable. Table 103 illustrates the increase in population of 14 of the principal urban communities and their associated suburbs from 1940 to 1950. It may be noted that the suburban populations of most of the cities have nearly doubled in the 10-year period, while those of Sacramento and Stockton have tripled, and that of Modesto has quadrupled.

TABLE 103

POPULATION OF PRINCIPAL URBAN CENTERS, CENTRAL VALLEY AREA

City	1940			1950		
	Within city limits	In suburbs	Total	Within city limits	In suburbs	Total
Sacramento	106,000	22,100	128,000	138,000	74,200	212,000
Fresno	60,700	22,100	82,800	91,700	38,900	131,000
Stockton	54,700	14,200	68,900	70,800	42,000	113,000
Bakersfield	29,200	23,100	52,300	34,800	66,900	102,000
Modesto	16,400	5,700	22,100	17,400	25,000	42,400
Marysville-Yuba City	11,600	6,000	17,600	15,700	12,000	27,700
Merced	10,100	3,300	13,400	15,300	8,100	23,400
Visalia	8,900	6,600	15,500	11,800	11,600	23,400
Porterville	6,300	5,200	11,500	6,900	12,300	19,200
Chico	9,300	3,100	12,400	12,300	6,500	18,800
Redding	8,100	5,800	13,900	10,300	7,500	17,800
Tulare	8,200	2,100	10,300	12,400	4,300	16,700
Lodi	11,100	1,200	12,300	13,800	1,900	15,700
Hanford	8,200	2,000	10,200	10,000	5,500	15,500

Agriculture, principally based on irrigation, is the major economic activity of the Central Valley Area, while the industry associated with agriculture provides a substantial portion of the income. Lands devoted to irrigated agriculture have increased continuously since the decade following 1850, when crops were first irrigated. By 1889, the first year in which the United States Census included data on irrigated agriculture, it was reported that approximately 635,000 acres were irrigated in the Central Valley Area.

At present about 4,750,000 acres, or approximately 57 per cent of the presently cultivated land in the area, are irrigated annually. The valley floor of the Central Valley is the largest and most important agricultural region of the State, producing a large variety of crops, while in the surrounding foothills are found important fruit-growing and stock-raising regions.

Prior to 1849, there was little activity in the Central Valley Area, the large ranchos being either undeveloped or devoted almost exclusively to stock raising. Captain John Sutter's New Helvetia, in the general area of present-day Sacramento, was the most highly developed of the ranchos, although the only field crop produced was dry-farmed wheat. The mining boom of 1849 and 1850 gave impetus to agriculture, the demand for agricultural produce and livestock increasing in direct ratio to the growth in population. Dry-farming methods provided much of the necessary grains and hay for a number of years, although irrigation was utilized for truck crops, and to some extent for alfalfa and pasture.

The first developments providing water to the irrigable lands of the Central Valley were simple earth ditches, conveying the summer flows of streams onto the adjacent lands. Later, as the mining ditches were abandoned, they were also utilized to serve lands farther removed from the flowing streams. One of the first irrigation diversions in the valley was a ditch constructed by James Moore in 1856, which delivered a flow of water at the rate of 2½ second-feet from Cache Creek to a tract of land in Yolo County. Serious interest in irrigated farming did not develop until 1864, which was a year of severe drought. Individual efforts dominated the first attempts to divert water onto the land, followed by the construction of irrigation canals for joint use through cooperative efforts by groups of farmers. As the population and the number of farms increased and the requirements for water grew, costly and complicated irrigation systems were built to supply the water necessary for successful agricultural developments. Stock companies were formed, and large amounts of capital were invested in irrigation enterprises. Nearly all of the summer flow of the streams was appropriated for use, and the necessity for storage of winter flood waters became evident.

In 1887 the Legislature passed the Wright Act, which was the forerunner of the present laws governing irrigation districts. This act and subsequent amendments provided the legal framework for the development of major irrigation water supply systems, as are now exemplified by many large and successful irrigation districts.

The majority of present water storage developments in the Central Valley Area have been constructed in the Sierra Nevada, although two reservoirs, East Park and Stony Gorge, are located on Stony Creek in the Coast Range. Shasta Reservoir on the Sacramento River, the key structure in the Central Valley Project, is another exception, as it is located in the Cascade Range. Two of the major structures in the Sierra Nevada were built primarily to provide urban water supplies for the San Francisco Bay Area. Hetch Hetchy Reservoir on the Tuolumne River serves the City of San Francisco, and Pardee Reservoir on the Mokelumne River provides a water supply for the Cities of Oakland, Berkeley, and other east bay communities.

Many of the major surface storage developments constructed in the Sierra Nevada, located on the principal streams of the area, have been planned primarily for irrigation water storage. The majority, however, have additional provisions for the development of hydroelectric power and for flood control. Major reservoir projects in use or under construction are Isabella on the Kern River, Pine Flat on the Kings River, Friant on the San Joaquin River, Exchequer on the Merced River, Don Pedro on the Tuolumne River, Melones on the Stanislaus River, Hogan on the Calaveras River, Folsom on the American River, and Lake Almanor on the North Fork of the Feather River. Many smaller reservoirs in the Sierra Nevada provide stream regulation for hydroelectric power development, and for irrigation in the mountain and foothill areas.

Irrigation districts, formed under enabling acts of the Legislature, are the principal irrigation water service agencies in the Central Valley Area. The 78 irrigation districts in the area reported approximately 1,650,000 acres irrigated in 1950. Despite the growing number of public water service agencies, there still remain several private agencies serving water to large tracts of land. These include such companies as the Kern County Land Company, Clear Lake Water Company, and Sutter Butte Canal Company. In recent years additional water developments, governmentally financed, have been provided by the United States Bureau of Reclamation, and to a lesser degree by other federal agencies such as the Corps of Engineers, the Indian Service, Soil Conservation Service, and Forest Service.

The Central Valley Project is the most recent comprehensive project for the irrigation of lands in the Central Valley. The original plans were made by the State of California, but the project is being constructed and operated by the Bureau of Reclamation. The project develops surplus waters in the Sacramento Valley for use on certain lands in the San Joaquin Valley that formerly used water from the San Joaquin River. This permits the diversion of the San Joaquin River water southward into the Tulare Lake Basin and northward to the Madera area. The principal features of the project are Shasta and Folsom Reservoirs in the Sacramento River Basin, and Friant Reservoir on the San Joaquin River; the Delta Cross Channel and the Delta-Mendota Canal, includ-

Harvesting Celery in the Delta

Courtesy Lodi Chamber of Commerce

Agriculture in Sacramento Valley

Courtesy State Division of Highways

ing the Tracy Pumping Plant, utilized to transfer water developed by the Sacramento River Basin reservoirs to the San Joaquin River area; and the Friant-Kern and Madera Canals to convey and distribute the water developed by Friant Reservoir. The sale of power from hydroelectric power plants at Shasta and Folsom Reservoirs will assist in financing the project. Other federally authorized units of the project are the Sacramento Valley Canals, the Sly Park Project in the Cosumnes River Basin, and the Contra Costa Canal which serves lands in Contra Costa County in the San Francisco Bay Area.

The outstanding characteristic of agricultural development in the Central Valley Area during recent decades has been the increasing utilization of ground water in the development of irrigated lands. In 1929 approximately 1,300,000 acres in the area were irrigated from ground water, portions of which also received a limited surface water supply. The 1950 United States Census of agriculture reported that land irrigated from ground water in the Central Valley Area amounted to 2,425,000 acres in 1949, while an additional 1,155,000 acres were served by combined surface and ground water supplies. A substantial part of the increased use of ground water has occurred on the west side of the San Joaquin Valley, where, during the period from 1929 to 1949, the irrigated area increased from 50,000 to 542,000 acres.

Lumbering and basic timber industrial installations in the Central Valley Area are centered in the Sierra Nevada, Cascade Range, Modoc Plateau, and a portion of the Coast Range. Plants for processing logging and milling residues to form timber by-products are located throughout the valley areas. Plywood, fiberboard, and pressed fireplace logs are among the products of the processing industry. A fiberboard products plant near Antioch produces about 325 tons of paper products daily, utilizing cull logs and mill residues from the Central Valley Area as well as from the North Coastal Area. Processing of lumber and timber by-products which result from logging operations in the Modoc Plateau generally takes place in the North Coastal Area and in Oregon.

The principal mineral producing activity in the Central Valley Area consists of the extraction of oil and gas in several fields in the southern San Joaquin Valley. Natural gas is found in widely scattered areas throughout the entire Central Valley. Gold mining, the early source of California's growth and development, which was centralized in the lower ranges of the Sierra Nevada, is no longer an important activity, largely because of the unfavorable price of gold. However, several large dredging operations are still maintained. Other mining activities in the Central Valley Area include the production of tungsten east of Fresno, mercury in the Coast Range west of Fresno, pyrites in the Redding area, gypsum near Fresno, and copper, lead, zinc, chromite, limestone, and cement in the foothills of the Sierra Nevada. Sands and gravels for aggregates are obtained commercially at many points in the valley.

The principal public utilities producing and distributing electric energy in the Central Valley Area are the Pacific Gas and Electric Company, with service extending throughout the major portion of the valley, and the Southern California Edison Company, serving Tulare County and small portions of Kings and Kern Counties in the southern portion of the valley. The California-Oregon Power Company provides service to a few communities in the area north of Shasta Dam. The Pacific Gas and Electric Company has hydroelectric generating plants on Sierra Nevada streams and on the Pit River, with an installed power capacity of 1,424,000 kilowatts, or 51 per cent of the total hydroelectric power development of the Central Valley Area. The Southern California Edison Company, with developments on the San Joaquin, Kaweah, Tule, and Kern Rivers, and the Bureau of Reclamation, with plants on the Sacramento and American Rivers, operate the remainder of the Central Valley Area's hydroelectric power installations.

The outstanding scenic attractions of the Sierra Nevada and other mountainous portions of the Central Valley Area, with their magnificent forests, lakes, and streams, have provided impetus for the establishment of innumerable commercial and private recreational areas. Major resorts are centered around such localities as Yosemite Valley, Clear Lake, Highways 40 and 50, and Lassen National Park, with smaller resorts and summer homes scattered throughout the entire mountain region.

Over the years there has been a notable development of industrial activity in the Central Valley Area. Much of this increase is closely allied with agriculture, but population growth has also given rise to many service industries. There is a present trend for industrial concerns based in the eastern United States to establish subsidiary plants in California. Such plants now produce a sizeable percentage of the requirements of the Pacific Coast states. Some of these plants have located in the Central Valley because of its strategic location as regards markets and transportation, the availability of raw materials, and the exceptional climate and living conditions. The area is believed to have a great potential for further development of industry.

The trend in urban development in the Central Valley Area has been toward centralizing the various commercial and industrial activities required for the economy of the surrounding farming areas in a number of strategically located communities. New urban centers have come into being with the growth in agriculture and population, and are expanding into the surrounding countryside. Cities such as Bakersfield, Fresno, Stockton, and Sacramento serve not

Harvesting Cotton
Near Bakersfield

Courtesy California State
Chamber of Commerce

Vineyards in
San Joaquin Valley

Courtesy Lodi Chamber
of Commerce

only their surrounding agricultural areas, but the entire economy of California.

In summary, it should be emphasized that the primary use of water in this area is for the production of agricultural crops. However, in the Central Valley Area, water is also utilized by urban communities, industrial plants, and for many additional purposes. In the mountains and foothills a large amount of hydroelectric power is generated at locations that combine appreciable heads with adequate water supplies. The streams and lakes constitute outstanding natural resources for recreational development and for propagation of fish life. Navigation on the Sacramento River forms an important part of the transportation facilities of the valley. River barges move agricultural produce from the valley, and import such items as gasoline, oil, and manufactured merchandise. Repulsion of sea water from channels of the Sacramento-San Joaquin Delta by release of stored fresh water has kept some 372,000 acres of rich, fertile farm land in the Delta from destruction. The Sacramento River Flood Control Project constitutes a comprehensive system of levees, overflow weirs, and by-pass channels that controls and conveys flood waters to the sea as rapidly as possible. An expected future increase in upstream water storage facilities, and a greater use of water for irrigation, will increase the degree of protection provided by the present system of flood control works. There is a demand for adequate sustained flows in the principal streams entering San Francisco Bay to permit the propagation of fish both for recreational and commercial catches. Although commercial fishing takes place off the coast and in the San Francisco Bay Area, the spawning and growth of the young of several important species take place in the Central Valley streams. Fish hatcheries are being provided to replace upstream spawning areas to which access is no longer possible.

There follows a presentation of available data and estimates pertinent to the nature and extent of water requirements in the Central Valley Area, both at the present time and under conditions of probable ultimate development.

PRESENT WATER SERVICE AREAS

As a necessary step in estimating the amount of the water requirement in the Central Valley Area, determinations were made of the location, nature, and extent of irrigated and urban and suburban water service areas. Remaining lands were not classified in detail with regard to their relatively minor miscellaneous types of water service, although such water service was given consideration in estimating the present water requirement.

Irrigated Lands

It was determined that under present conditions of development in the Central Valley Area, about 4,751,000 acres are irrigated in a given year, on the average. This constitutes approximately 70 per cent of the land irrigated throughout California. Some 22 per cent of this total, or 1,032,000 acres, is in the Sacramento River Basin; 41 per cent, or 1,957,000 acres, is in the San Joaquin River Basin; and the remaining 37 per cent, or 1,762,000 acres, is in the Tulare Lake Basin.

The irrigated crops produced in the Central Valley Area are illustrative of the extreme diversification of agriculture in California. A substantial acreage of rice is produced in the trough of the Sacramento Valley, while cotton has become the dominant crop in the San Joaquin Valley and the Tulare Lake Basin. Irrigated orchards and vineyards are found throughout the entire area wherever soils are sufficiently deep or properly drained. Citrus fruits are produced in an extensive orchard belt on the east side of the Tulare Lake Basin, and to a small extent in Glenn and Butte Counties in the northern portion of the Sacramento Valley. Improved farming equipment and greater profit margins in the last decade have made possible the levelling and irrigation of land formerly considered too rough for successful agricultural development. Considerable acreages of foothill and mountain lands are now irrigated by sprinklers, a method found to be successful for applying water to orchards and pasture on lands of rolling topography. Although extensive areas are devoted to so-called truck or ''cash'' crops, a substantial portion of the irrigated land in the Central Valley Area is used for production of forage. Livestock raising continues to be one of the important agricultural pursuits of the area.

The field surveys providing the basis for determination of irrigated acreage in the Central Valley Area were accomplished during the period from 1946 through 1950, by several agencies and with varying standards and degrees of accuracy. Information regarding the dates of field mapping and sources of data are contained in Appendix D. Based on the available survey data, the irrigated lands were classified into various crop groups, with a view to segregating those of similar water use. The detailed segregation of individual truck and nursery crops was found to be impracticable. In some localities, data on the acreage planted to a few of the dominant truck crops were available. However, as similar data were not available throughout the area, all crops of this nature were grouped under the general heading of truck crops. In the San Joaquin River and Tulare Lake Basins, acreages of irrigated hay and grain crops were segregated from the acreage of other field crops, but in the Sacramento River Basin such segregation was not possible in all cases. Requirements for applied water were computed, however, on the actual area cropped to hay and grain, where applicable data were available, and are reported in the appropriate tables. Therefore, all field crops including hay and

Urban Development in Central Valley Area

Courtesy State Division of Highways

Irrigation in the Delta

Courtesy Armco Drainage and Metal Products, Inc.

grain were classified as one group for that basin. A list of the various crop groups into which irrigated lands of the Central Valley Area were classified follows:

Alfalfa	Hay, seed, and pasture
Pasture	Grasses and legumes, other than alfalfa, used for livestock forage
Orchard	Deciduous fruit, nuts, and olives
Citrus	Oranges, grapefruit, lemons
Vineyard	All varieties of grapes
Truck crops	Intensively cultivated fresh vegetables, including tomatoes, lettuce, melons, potatoes, and nursery crops
Rice	
Cotton	
Hay and grain	Barley, wheat, and other grains used as cereal or forage
Miscellaneous field crops	Dried beans, milo, corn, hops, sugar beets, and unsegregated hay and grain in Sacramento River Basin

It is estimated that approximately 108,000 acres in the Central Valley Area are occupied by farm lots at the present time. Of this total, 45,200 acres lie in the San Joaquin River Basin, 41,500 in the Tulare Lake Basin, and 21,400 in the Sacramento River Basin. These consist of farm buildings and areas immediately surrounding them that receive water service.

Summaries of presently irrigated acreages within the Central Valley Area by the various crop groups are presented in Tables 104 and 105. Table 104 lists the acreages by hydrographic units, and Table 105 by counties.

Urban and Suburban Water Service Areas

It was determined that under present conditions of development in the Central Valley Area, approximately 191,000 acres are devoted to urban and suburban types of land use. On the floor of the valley, the urban and suburban areas were determined as part of the field surveys of irrigated lands previously mentioned. In the more mountainous regions, however, such areas were determined by examination of maps and plates, and by the application of appropriate density factors to available population data. For the most part, the business, commercial, and industrial establishments and surrounding homes included in this areal classification receive a municipal type of water supply. Areas of urban and suburban water service within each hydrographic unit of the Central Valley Area are listed in Table 106, and within each county in Table 107. It should be noted that areas shown are gross acreages, as streets and intermingled undeveloped lands that are a part of the urban type of community are included.

Unclassified Areas

Remaining lands in the Central Valley Area, other than those that are irrigated or urban and suburban in character, were not classified in detail as regards present water service. However, of a total of about 32,930,000 acres of such remaining lands less than 85,000 acres actually receive water service at the present time. These relatively minor service areas consist of scattered developed portions of national forests and monuments, public parks, private recreational areas, military reservations, wild fowl refuges, etc.

Migratory waterfowl reserves, feeding areas, and gun clubs occupy approximately 62,000 acres in the Central Valley Area, of which about 15,000 acres are federal and state wild fowl management areas. The remaining acreage is composed of land utilized throughout the growing season to produce rice, but flooded late in the fall to attract wild fowl during the hunting season.

National forests, monuments, and parks include nearly 13,000,000 acres of land in the Central Valley Area. For the most part, this land is in the mountainous regions and is covered by timber, native brush, and grass. A small portion, estimated to be about 136,000 acres, is presently irrigated, and is included in the values listed in Tables 104 and 105. There are many minor water service areas, consisting of scattered developments such as public camp and picnic areas, summer residences, trailer camps, administration buildings, etc., in the forests and parks. It was estimated that approximately 5,000 acres in the Central Valley Area are devoted to these types of development, in which the use of water is minor in amount. The Division of Beaches and Parks of the State Department of Natural Resources at present administers 20 parks and historical monuments throughout the area. These aggregate nearly 10,000 acres, but only small portions are devoted to permanent buildings, grounds, and camping and picnic areas requiring domestic water service. The area of privately owned recreational developments in the Central Valley Area was not estimated, as it is scattered generally throughout the Sierra Nevada and the Cascade and Coast Ranges, principally in the form of summer cabins and camps.

Military establishments within the Central Valley Area total about 175,000 acres, but the water-using portion is relatively small, consisting principally of administration buildings, warehouses, and quarters for personnel. The use of water in such establishments is similar to the domestic and industrial requirements of urban areas, and the requirements were established on that basis.

TABLE 104

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Rice	Cotton*	Hay and grain*	Miscellaneous field crops	Net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
	Sacramento River Basin														
	Mountain Units														
1	Goose Lake	1,800	2,300	200	0	0	100	0	----	----	3,700	8,100	100	200	8,400
2	Pit River	10,500	31,500	100	0	0	300	0	----	----	62,000	104,000	1,300	2,600	108,000
3	McCloud River	0	1,800	0	0	0	0	0	----	----	0	1,800	0	100	1,900
4	Sacramento River above Shasta Dam	0	1,300	0	0	0	100	0	----	----	200	1,600	0	100	1,700
5	West Side, Shasta Dam to Cottonwood Creek	0	400	800	0	0	100	0	----	----	200	1,500	0	100	1,600
6	East Side, Cow Creek to Paynes Creek	400	2,900	200	0	0	400	0	----	----	500	4,400	100	100	4,600
7	Red Bluff to Thomes Creek	0	0	0	0	0	0	0	----	----	0	0	0	0	0
8	Antelope to Mud Creek	0	800	700	0	0	0	0	----	----	0	1,500	0	100	1,600
9	Stony Creek	0	300	0	0	0	0	0	----	----	300	600	0	0	600
10	Butte and Chico Creeks	0	200	1,800	0	0	100	0	----	----	0	2,100	0	100	2,200
11	Cortina Creek	0	0	0	0	0	0	0	----	----	0	0	0	0	0
12	Feather River	1,700	73,300	4,700	300	----	----	700	----	----	2,400	83,100	1,000	2,100	86,200
13	Yuba and Bear Rivers	0	14,400	7,700	0	200	0	0	----	----	400	22,700	300	600	23,600
14	Cache Creek	1,200	2,100	4,400	0	0	0	0	----	----	900	8,600	100	300	9,000
15	American River	0	2,700	22,000	0	900	0	0	----	----	200	25,800	300	1,100	27,200
16	Putah Creek	1,000	400	700	0	0	1,000	0	----	----	200	3,300	0	200	3,500
	Subtotals, Mountain Units	16,600	134,000	43,300	300	1,100	2,100	700	----	----	71,000	269,000	3,200	7,700	280,000
	Valley Units														
17	Anderson-Cottonwood	1,700	14,100	400	0	200	200	0	----	----	300	16,900	300	1,300	18,500
18	Tehama	2,200	6,700	4,100	0	0	100	0	----	----	600	13,700	700	3,700	18,100
19	Vina	4,100	3,600	10,500	0	0	300	0	----	----	1,900	20,400	500	5,100	26,000
20	Orland	7,000	16,800	6,400	700	100	200	200	----	----	1,200	32,600	1,100	4,100	37,800
21	Chico	2,100	4,400	8,200	0	0	200	15,400	----	----	2,100	32,400	800	3,300	36,500
22	Arbuckle	2,500	1,800	9,400	0	300	2,300	3,600	----	----	2,200	22,100	900	3,900	26,900
23	Colusa Trough	10,800	30,200	11,900	0	0	6,100	131,000	----	----	43,400	233,000	4,100	13,700	251,000
24	Feather River to Butte Slough	14,000	14,600	20,400	300	200	3,000	44,600	----	----	3,600	101,000	2,100	8,400	111,000
25	Yuba	2,700	5,700	21,800	0	100	2,400	9,200	----	----	3,200	45,100	900	2,900	48,900
26	Marysville-Sheridan	3,900	15,000	12,500	0	100	1,500	15,200	----	----	9,700	57,900	1,400	5,300	64,600
27	Woodland	8,900	5,500	9,400	0	700	9,600	21,400	----	----	6,300	61,800	1,500	4,000	67,300
28	Carmichael	3,600	19,500	4,800	0	6,800	2,000	6,300	----	----	4,300	47,300	1,500	4,700	53,500
29	Dixon	5,400	5,700	7,300	0	0	1,400	0	----	----	4,100	23,900	1,300	2,800	28,000
30	Yolo	10,500	8,600	600	0	0	5,900	21,700	----	----	7,900	55,200	1,100	5,400	61,700
	Subtotals, Valley Units	79,400	152,000	128,000	1,000	8,500	35,200	268,000	----	----	90,800	763,000	18,200	68,600	850,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	96,000	286,000	171,000	1,300	9,600	37,300	269,000	----	----	162,000	1,032,000	21,400	76,300	1,130,000
	Tulare Lake Basin														
	Mountain Units														
31	West Side, Kern County	0	0	0	0	0	0	0	0	0	0	0	0	0	0
32	Kern River and Tehachapi Mountains	2,500	3,800	100	0	0	1,300	0	0	600	1,000	9,300	100	200	9,600
33	Tule River	0	700	500	200	0	0	0	0	0	0	1,400	0	0	1,400
34	Kaweah River	0	100	0	0	0	0	0	0	0	0	100	0	0	100
35	Kings River	0	800	0	0	0	0	0	0	0	0	800	0	0	800
	Subtotals, Mountain Units	2,500	5,400	600	200	0	1,300	0	0	600	1,000	11,600	100	200	11,900

TABLE 104—Continued

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

(In acres)

Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Rice	Cotton*	Hay and grain*	Miscellaneous field crops	Net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
	Valley Units														
36	Antelope Plain	0	0	300	0	0	300	0	11,700	14,100	9,800	36,200	3,700	8,300	48,200
37	Kern	54,100	26,900	3,000	1,700	27,400	58,500	0	216,000	41,200	23,100	452,000	10,400	19,700	482,000
38	Earlimart	25,700	11,400	5,400	9,200	27,100	11,700	0	35,100	23,000	2,200	151,000	3,400	7,200	162,000
39	Visalia	46,900	31,800	26,300	28,200	31,200	3,800	0	52,900	20,900	1,600	244,000	5,400	11,300	261,000
40	Fresno-Hanford	61,100	103,000	49,300	2,800	231,000	5,400	700	167,000	59,400	300	680,000	14,700	28,800	723,000
41	Tulare Lake	11,600	1,800	0	0	0	0	0	54,800	118,000	1,000	187,000	3,800	7,500	198,000
	Subtotals, Valley Units	199,000	175,000	84,300	42,000	317,000	79,700	700	537,000	277,000	38,000	1,750,000	41,400	82,800	1,874,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	202,000	180,000	84,900	42,200	317,000	81,000	700	537,000	278,000	39,000	1,762,000	41,500	83,000	1,886,000
	San Joaquin River Basin														
	Mountain Units														
42	Mount Diablo	0	0	0	0	0	0	0	0	0	0	0	0	0	0
43	Altamont to San Luis Creek	0	0	0	0	0	0	0	0	0	0	0	0	0	0
44	West Side, Los Banos Creek to Avenal Creek	0	100	0	0	0	100	0	100	0	1,200	1,500	0	0	1,500
45	San Joaquin River	0	2,500	0	0	0	0		0	0	0	2,500	100	100	2,700
46	Chowchilla-Fresno Rivers	0	200	300	0	0	0	0	0	0	0	500	0	0	500
47	Merced River	0	600	100	0	0	0	0	0	0	0	700	0	0	700
48	Tuolumne River	0	500	900	0	0	0	0	0	0	0	1,400	0	0	1,400
49	Stanislaus River	0	700	200	0	0	0	0	0	0	0	900	0	0	900
50	Mokelumne-Calaveras Rivers	0	1,000	300	0	0	0	0	0	0	0	1,300	0	0	1,300
51	Cosumnes River	0	100	100	0	0	0	0	0	0	0	200	0	0	200
	Subtotals, Mountain Units	0	5,700	1,900	0	0	100	0	100	0	1,200	9,000	100	100	9,200
	Valley Units														
52	Antioch	16,000	4,900	14,000	0	900	6,100	400	0	6,400	3,800	52,500	1,300	3,400	57,200
53	Delta-Mendota	2,300	300	600	0	0	3,500	0	0	6,700	6,000	19,400	600	1,500	21,500
54	West Side, San Joaquin Valley	6,400	500	800	0	0	29,600	1,600	89,100	222,000	19,000	369,000	3,900	7,500	381,000
55	Madera	28,000	20,900	5,800	0	23,900	2,200	700	58,100	15,400	4,300	159,000	7,800	15,300	182,000
56	Merced	31,000	69,600	23,300	0	12,300	7,900	4,300	17,200	20,000	2,600	188 000	5,800	12,400	206,000
57	Los Banos	77,600	17,800	1,900	0	0	6,900	8,300	21,700	37,300	9,700	181,000	3,000	7,300	191,000
58	Modesto	44,600	58,600	33,000	0	24,000	7,400	500	100	37,300	19,300	225,000	6,300	12,700	244,000
59	Vernalis	20,600	3,000	4,000	0	200	10,600	800	0	6,100	12,800	58,100	1,100	2,500	61,700
60	Oakdale	20,000	66,000	14,200	0	15,800	8,400	2,200	0	8,800	7,300	143,000	2,500	6,600	152,000
61	Stockton	11,200	56,900	25,800	0	43,600	16,200	6,100	0	0	16,500	176,000	5,400	15,600	197,000
62	Ione	300	1,400	600	1,500	0	500	0	0	0	300	4,600	1,300	2,700	8,600
63	Sacramento-San Joaquin Delta	28,800	23,700	5,500	0	0	128,000	700	0	119,000	66,100	372,000	6,100	17,800	396,000
	Subtotals, Valley Units	287,000	324,000	129,000	1,500	121,000	228,000	25,600	186,000	479,000	168,000	1,948,000	45,100	105,000	2,098,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	287,000	329,000	131,000	1,500	121,000	228,000	25,600	186,000	479,000	169,000	1,957,000	45,200	105,000	2,107,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	585,000	795,000	387,000	45,000	448,000	346,000	295,000	723,000	757,000	370,000	4,751,000	108,000	265,000	5,123,000

* Included with Miscellaneous Field Crops.

Navigation on Sacramento River

Courtesy The River Lines

Hydroelectric Power Plant on the Feather River

Photograph by State Division of Water Resources

TABLE 105

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN COUNTIES, CENTRAL VALLEY AREA

(In acres)

County	Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Rice	Cotton	Hay and grain	Miscellaneous field crops	Net irrigated area	Farm lots	Included non-water service areas	Approximate gross area
Alameda	800	400	300	0	0	100	0	0	0	800	2,400	100	200	2,700
Alpine	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amador	100	500	0	0	0	100	0	0	0	200	900	200	400	1,500
Butte	15,900	17,700	29,100	1,300	100	1,600	47,100	0	0	3,000	116,000	2,300	10,300	129,000
Calaveras	0	1,300	600	0	0	100	0	0	0	0	2,000	0	0	2,000
Colusa	4,600	11,400	15,200	0	200	1,800	63,400	0	0	8,000	105,000	2,600	10,700	118,000
Contra Costa	16,800	7,500	12,400	0	900	18,100	100	0	10,800	6,900	73,500	1,400	4,400	79,300
El Dorado	0	1,500	6,500	0	0	0	0	0	0	0	8,000	100	300	8,400
Fresno	57,700	42,600	42,100	3,900	196,000	35,400	4,500	199,000	264,000	15,200	859,000	17,200	5,900	882,000
Glenn	12,900	33,900	9,300	0	100	400	35,500	0	0	4,000	96,100	1,900	7,400	105,000
Kern	55,900	30,000	3,400	1,400	27,400	59,800	0	216,000	46,300	24,100	464,000	11,900	23,000	499,000
Kings	27,400	39,700	7,300	0	13,400	400	0	120,000	145,000	18,500	372,000	7,100	49,700	429,000
Lake	1,700	2,500	4,400	0	0	1,100	0	0	0	1,000	10,700	100	500	11,300
Lassen	2,600	10,000	0	0	0	0	0	0	0	10,800	23,400	300	500	24,200
Madera	28,000	22,500	5,800	0	23,900	2,300	700	58,100	15,400	4,300	161,000	7,900	15,400	184,000
Mariposa	0	200	300	0	0	0	0	0	0	0	500	0	0	500
Merced	109,000	95,200	29,300	0	16,100	15,900	10,400	34,700	52,200	20,200	383,000	9,500	21,100	414,000
Modoc	7,900	19,400	300	0	0	200	0	0	0	41,100	68,900	800	1,800	71,500
Napa	500	0	700	0	0	0	0	0	0	0	1,200	0	0	1,200
Nevada	0	4,900	1,500	0	100	0	0	0	0	200	6,700	100	200	7,000
Placer	400	9,700	23,200	0	1,900	400	4,400	0	0	1,400	41,400	600	2,100	44,100
Plumas	1,000	49,100	100	0	0	0	0	0	0	2,100	52,300	700	1,500	54,500
Sacramento	18,300	36,800	8,200	1,500	5,900	14,900	6,000	0	36,500	25,600	154,000	4,500	13,600	172,000
San Benito	0	100	0	0	0	100	0	100	0	1,200	1,500	0	0	1,500
San Joaquin	44,800	70,400	30,400	0	57,900	118,000	6,800	0	62,900	48,600	440,000	10,000	27,400	477,000
San Luis Obispo	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Shasta	3,900	23,100	1,500	0	200	800	0	0	0	11,200	40,700	1,000	700	42,400
Sierra	700	19,000	0	0	0	0	0	0	0	4,900	24,600	300	600	25,500
Siskiyou	100	2,900	0	0	0	0	0	0	0	0	3,000	0	200	3,200
Solano	7,300	10,400	7,600	0	0	6,600	0	0	12,200	16,900	61,000	2,700	6,600	70,300
Stanislaus	53,900	104,000	44,300	0	21,400	14,700	3,500	100	54,400	16,600	314,000	7,300	15,900	337,000
Sutter	9,100	16,400	39,000	0	700	8,900	56,300	0	0	39,600	170,000	3,000	11,100	184,000
Tehama	5,200	13,100	9,900	0	0	400	0	0	0	1,500	30,100	1,400	9,200	40,700
Tulare	75,700	71,000	32,500	36,900	80,400	16,300	0	94,800	49,000	3,700	460,000	9,700	13,000	483,000
Tuolumne	0	400	1,000	0	0	0	0	0	0	0	1,400	0	0	1,400
Ventura	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Yolo	19,200	10,400	11,500	0	800	26,100	44,900	0	7,600	29,600	150,000	2,200	6,900	159,000
Yuba	3,600	17,300	9,600	0	100	1,200	12,100	0	0	8,500	52,400	1,200	4,100	57,700
APPROXIMATE TOTALS, CENTRAL VALLEY AREA	585,000	795,000	387,000	45,000	448,000	346,000	295,000	723,000	757,000	370,000	4,751,000	108,000	265,000	5,123,000

Summary

Table 106 comprises a summary of present water service areas within hydrographic units of the Central Valley Area. A similar summary for counties of the area is presented in Table 107.

PROBABLE ULTIMATE WATER SERVICE AREAS

To aid in estimating the amount of water that will ultimately be utilized in the Central Valley Area, projections were first made to determine the probable ultimate irrigated and urban and suburban water service areas. It was assumed that the remaining lands, for convenience referred to as "other water service areas," ultimately will be served with water commensurate with their needs.

Irrigated Lands

Based on data from land classification surveys, it was estimated that a gross area of approximately 11,750,000 acres in the Central Valley Area is suitable for irrigated agriculture. Excepting farm lots and certain lands within the gross area that experience indicates will never be served with water, such as lands occupied by roads, railroads, etc., it was estimated that under ultimate conditions of development a net area of approximately 10,040,000 acres will actually be irrigated. Table 108 presents these estimates for hydrographic units of the Central Valley Area, and Table 109 for the various counties.

The probable ultimate crop pattern for irrigated lands of the Central Valley Area is presented in Table 110. The crop grouping parallels that used in the case of present development except for the added group titled "Sugar beets." This group was of minor importance and not segregated in the case of the present crop pattern, but is expected to be of greater significance in the future.

TABLE 106

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands	Urban and suburban areas	Approximate total
	Sacramento River Basin			
	Mountain Units			
1	Goose Lake	8,400	100	8,500
2	Pit River	108,000	1,700	110,000
3	McCloud River	1,900	900	2,800
4	Sacramento River above Shasta Dam	1,700	1,200	2,900
5	West Side, Shasta Dam to Cottonwood Creek	1,600	200	1,800
6	East Side, Cow Creek to Paynes Creek	4,600	1,000	5,600
7	Red Bluff to Thomes Creek	0	0	0
8	Antelope to Mud Creek	1,600	0	1,600
9	Stony Creek	600	100	700
10	Butte and Chico Creeks	2,200	600	2,800
11	Cortina Creek	0	0	0
12	Feather River	86,200	5,700	91,900
13	Yuba and Bear Rivers	23,600	2,200	25,800
14	Cache Creek	9,000	1,300	10,300
15	American River	27,200	3,600	30,800
16	Putah Creek	3,500	200	3,700
	Subtotals, Mountain Units	280,000	18,800	299,000
	Valley Units			
17	Anderson-Cottonwood	18,500	2,500	21,000
18	Tehama	18,100	1,300	19,400
19	Vina	26,000	1,800	27,800
20	Orland	37,800	1,100	38,900
21	Chico	36,500	5,400	41,900
22	Arbuckle	26,900	200	27,100
23	Colusa Trough	251,000	1,600	253,000
24	Feather River to Butte Slough	111,000	1,800	113,000
25	Yuba	48,900	1,900	50,800
26	Marysville-Sheridan	64,600	3,300	67,900
27	Woodland	67,300	3,300	70,600
28	Carmichael	53,500	55,000	108,500
29	Dixon	28,000	2,100	30,100
30	Yolo	61,700	500	62,200
	Subtotals, Valley Units	850,000	81,800	932,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	1,130,000	101,000	1,231,000
	Tulare Lake Basin			
	Mountain Units			
31	West Side, Kern County	0	0	0
32	Kern River and Tehachapi Mountains	9,600	500	10,100
33	Tule River	1,400	100	1,500
34	Kaweah River	100	0	100
35	Kings River	800	0	800
	Subtotals, Mountain Units	11,900	600	12,500
	Valley Units			
36	Antelope Plain	48,200	1,600	49,800
37	Kern	482,000	18,800	501,000
38	Earlimart	162,000	1,500	163,000
39	Visalia	261,000	6,700	268,000
40	Fresno-Hanford	723,000	20,500	744,000
41	Tulare Lake	198,000	300	198,000
	Subtotals, Valley Units	1,874,000	49,400	1,924,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	1,886,000	50,000	1,936,000
	San Joaquin River Basin			
	Mountain Units			
42	Mount Diablo	0	0	0
43	Altamont to San Luis Creek	0	0	0
44	West Side, Los Banos Creek to Avenal Creek	1,500	100	1,600
45	San Joaquin River	2,700	0	2,700
46	Chowchilla-Fresno Rivers	500	100	600
47	Merced River	700	300	1,000
48	Tuolumne River	1,400	1,000	2,400
49	Stanislaus River	900	400	1,300
50	Mokelumne-Calaveras Rivers	1,300	1,000	2,300
51	Cosumnes River	200	1,200	1,400
	Subtotals, Mountain Units	9,200	4,100	13,300
	Valley Units			
52	Antioch	57,200	2,700	59,900
53	Delta-Mendota	21,500	100	21,600
54	West Side, San Joaquin Valley	381,000	1,400	382,000
55	Madera	182,000	2,700	185,000
56	Merced	206,000	4,700	211,000
57	Los Banos	191,000	1,600	193,000
58	Modesto	244,000	4,800	249,000
59	Vernalis	61,700	400	62,100
60	Oakdale	152,000	3,100	155,000
61	Stockton	197,000	12,900	210,000
62	Ione	8,600	300	8,900
63	Sacramento-San Joaquin Delta	396,000	1,100	397,000
	Subtotals, Valley Units	2,098,000	35,800	2,134,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	2,107,000	39,900	2,147,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	5,123,000	191,000	5,314,000
	Unclassified areas receiving water service			84,700
	APPROXIMATE TOTAL, PRESENT WATER SERVICE AREA			5,399,000

Urban and Suburban Water Service Areas

It is expected that urban and suburban growth in the Central Valley Area generally will be associated with further development of agriculture, and that the problems of producing, processing, and exporting the diversity of agricultural commodities will continue to be the basic source of business activity. Population increase may also be brought about by expansion of present and new industries. The greatest development is expected to occur in those cities adjacent to transportation facilities importing and

TABLE 107

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN COUNTIES, CENTRAL VALLEY AREA

(In acres)

County	Irrigated lands	Urban and suburban areas	Approximate total
Alameda	2,700	0	2,700
Alpine	0	0	0
Amador	1,500	1,500	3,000
Butte	129,000	10,600	140,000
Calaveras	2,000	1,000	3,000
Colusa	118,000	1,300	119,000
Contra Costa	79,300	1,800	81,100
El Dorado	8,400	1,400	9,800
Fresno	882,000	19,300	901,000
Glenn	105,000	1,500	107,000
Kern	499,000	20,100	519,000
Kings	429,000	3,200	432,000
Lake	11,300	1,400	12,700
Lassen	24,200	700	24,900
Madera	184,000	2,800	187,000
Mariposa	500	300	800
Merced	414,000	5,800	420,000
Modoc	71,500	1,000	72,500
Napa	1,200	100	1,300
Nevada	7,000	1,300	8,300
Placer	44,100	4,900	49,000
Plumas	54,500	1,800	56,300
Sacramento	172,000	53,300	225,000
San Benito	1,500	0	1,500
San Joaquin	477,000	15,700	493,000
San Luis Obispo	0	0	0
Shasta	42,400	4,500	46,900
Sierra	25,500	200	25,700
Siskiyou	3,200	1,900	5,100
Solano	70,300	2,400	72,700
Stanislaus	337,000	7,000	344,000
Sutter	184,000	2,400	186,000
Tehama	40,700	3,100	43,800
Tulare	483,000	9,100	492,000
Tuolumne	1,400	1,400	2,800
Ventura	0	0	0
Yolo	159,000	4,500	164,000
Yuba	57,700	3,400	61,100
APPROXIMATE TOTALS, CENTRL VALLEY AREA	5,123,000	191,000	5,314,000
Unclassified areas receiving water service			84,700
APPROXIMATE TOTAL, PRESENT WATER SERVICE AREA			5,399,000

exporting commodities to and from the great Central Valley. It was estimated that under ultimate conditions of development the urban and suburban water service areas will increase to approximately 292,000 acres.

Urban and suburban types of land use are expected to occupy the same localities as at present, but vacant lands will be filled and densities increased. In addition, it is probable that encroachment will occur on surrounding lands in an estimated amount of about 105,000 acres. For purposes of the present studies no attempt was made to delineate the boundaries of such encroachment, nor to determine what proportion will be on irrigable lands. The estimate of probable ultimate urban and suburban water service areas is included in Table 112. It should be noted that the areas shown are gross acreages, including streets, vacancies, etc.

Other Water Service Areas

Remaining lands of the Central Valley Area, not classified as irrigable or urban and suburban under conditions of ultimate development, aggregate about 26,010,000 acres, or 68 per cent of the area. As previously mentioned, it was assumed that ultimately these lands will be served with water in amounts sufficient for their needs. No attempt was made to segregate these "other water service areas" in detail in regard to the nature of their probable ultimate water service. However, as shown in Table 111, they were broken down for convenience in estimating water requirements into those portions inside and outside of national forests, monuments, and military reservations, and above and below an elevation of 3,000 feet. The lands classified as "other water service areas" include recreational developments, both public and private, military establishments, residential and industrial types of land use outside of urban communities, wild fowl refuges, etc. Most of the lands are situated in rough mountainous terrain, much of which is presently inaccessible. It is expected that even under conditions of ultimate development these lands will be only sparsely settled, and will have very minor requirements for water service.

Summary

Table 112 comprises a summary of probable ultimate water service areas, segregated into irrigable lands, urban and suburban areas, and other water service areas.

UNIT VALUES OF WATER USE

Information obtained during recent investigations of the water resources of Sutter, Yuba, Placer, and San Joaquin Counties, and experimental data from the University of California at Davis, provided much of the basis for estimating unit values of water use in the Central Valley Area. These data were modified by standard methods to provide complete coverage of the area.

Irrigation Water Use

In general, unit seasonal values of consumptive use of water on lands devoted to the various irrigated crops were computed by the methods outlined in Chapter II. Individual analysis was made in order to determine the unit seasonal values of consumptive use for rice, hay and grain, and winter potatoes, for which the growing seasons and cultural practices were not readily adaptable to the standard procedure. The methods used for these crops are described in Chapter II.

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TABLE 108

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
	Sacramento River Basin				
	Mountain Units				
1	Goose Lake	29,400	300	4,000	25,100
2	Pit River	400,000	4,300	49,500	346,000
3	McCloud River	25,100	300	3,200	21,600
4	Sacramento River above Shasta Dam	10,900	100	1,500	9,800
5	West Side, Shasta Dam to Cottonwood Creek	41,100	500	4,500	36,100
6	East Side, Cow Creek to Paynes Creek	105,000	1,100	13,300	90,300
7	Red Bluff to Thomes Creek	52,200	500	6,800	44,900
8	Antelope to Mud Creek	13,000	100	1,600	11,300
9	Stony Creek	52,700	600	7,200	44,900
10	Butte and Chico Creeks	19,400	200	2,800	16,400
11	Cortina Creek	52,400	500	6,900	45,000
12	Feather River	246,000	2,500	50,900	193,000
13	Yuba and Bear Rivers	166,000	1,800	29,400	135,000
14	Cache Creek	77,200	1,000	9,500	66,700
15	American River	110,000	1,400	17,100	91,800
16	Putah Creek	43,100	400	5,300	37,400
	Subtotals, Mountain Units	1,444,000	15,600	213,000	1,215,000
	Valley Units				
17	Anderson-Cottonwood	28,400	400	3,500	24,500
18	Tehama	101,000	1,300	12,400	87,700
19	Vina	82,300	1,200	9,400	71,700
20	Orland	137,000	1,700	15,500	120,000
21	Chico	91,300	2,300	10,100	78,900
22	Arbuckle	119,000	1,400	13,300	104,000
23	Colusa Trough	507,000	5,900	65,300	436,000
24	Feather River to Butte Slough	245,000	3,100	33,700	208,000
25	Yuba	74,200	1,200	8,600	64,000
26	Marysville-Sheridan	200,000	2,400	33,900	164,000
27	Woodland	180,000	2,100	21,100	157,000
28	Carmichael	236,000	2,800	37,700	196,000
29	Dixon	165,000	2,300	19,400	143,000
30	Yolo	180,000	2,000	24,500	153,000
	Subtotals, Valley Units	2,346,000	30,100	308,000	2,008,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	3,790,000	45,700	521,000	3,223,000
	Tulare Lake Basin				
	Mountain Units				
31	West Side, Kern County	11,700	200	1,500	10,000
32	Kern River and Tehachapi Mountains	181,000	2,400	19,500	159,000
33	Tule River	31,800	500	3,800	27,500
34	Kaweah River	15,800	200	1,900	13,700
35	Kings River	11,900	100	1,300	10,500
	Subtotals, Mountain Units	252,000	3,400	28,000	221,000
	Valley Units				
36	Antelope Plain	451,000	7,600	56,500	387,000
37	Kern	962,000	15,000	118,000	829,000
38	Earlimart	394,000	6,300	48,700	339,000
39	Visalia	419,000	5,400	47,400	366,000
40	Fresno-Hanford	1,005,000	17,200	125,000	863,000
41	Tulare Lake	254,000	3,900	33,600	216,000
	Subtotals, Valley Units	3,485,000	55,400	429,000	3,000,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	3,737,000	58,800	457,000	3,221,000
	San Joaquin River Basin				
	Mountain Units				
42	Mount Diablo	12,000	200	1,300	10,500
43	Altamont to San Luis Creek	33,800	400	3,900	29,500
44	West Side, Los Banos Creek to Avenal Creek	50,400	700	6,200	43,500
45	San Joaquin River	5,000	0	100	4,900
46	Chowchilla-Fresno Rivers	24,500	300	3,800	20,400
47	Merced River	44,600	400	9,600	34,600
48	Tuolumne River	37,900	500	5,700	31,700
49	Stanislaus River	26,100	300	5,100	20,700
50	Mokelumne-Calaveras Rivers	68,900	1,100	14,100	53,700
51	Cosumnes River	62,200	800	10,400	51,000
	Subtotals, Mountain Units	365,000	4,700	60,200	300,000
	Valley Units				
52	Antioch	67,200	1,300	7,400	58,500
53	Delta-Mendota	72,100	1,000	7,500	63,600
54	West Side, San Joaquin Valley	785,000	11,400	91,000	683,000
55	Madera	422,000	6,200	56,500	359,000
56	Merced	463,000	6,100	70,200	387,000
57	Los Banos	293,000	4,100	37,600	251,000
58	Modesto	384,000	6,300	52,200	326,000
59	Vernalis	82,100	1,200	8,600	72,300
60	Oakdale	214,000	3,500	27,500	183,000
61	Stockton	489,000	6,900	80,200	402,000
62	Ione	150,000	1,900	33,000	115,000
63	Sacramento-San Joaquin Delta	439,000	6,400	37,400	395,000
	Subtotals, Valley Units	3,860,900	56,300	509,000	3,295,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	4,225,000	61,000	569,000	3,595,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	11,750,000	166,000	1,547,000	10,040,000

TABLE 109

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN COUNTIES, CENTRAL VALLEY AREA

(In acres)

County	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
Alameda	3,900	100	500	3,300
Alpine	300	0	0	300
Amador	68,000	700	13,000	54,300
Butte	393,000	4,300	65,400	323,000
Calaveras	98,900	900	19,300	78,700
Colusa	373,000	4,300	48,100	321,000
Contra Costa	86,000	1,500	2,100	82,400
El Dorado	91,700	1,000	15,500	75,200
Fresno	1,470,000	18,900	181,000	1,270,000
Glenn	318,000	3,700	37,000	277,000
Kern	1,411,000	18,100	175,000	1,218,000
Kings	695,000	20,900	74,900	599,000
Lake	78,700	900	9,500	68,300
Lassen	104,000	1,300	14,200	88,500
Madera	445,000	8,000	55,900	381,000
Mariposa	47,700	400	10,400	36,900
Merced	787,000	11,000	109,000	667,000
Modoc	228,000	2,300	27,000	199,000
Napa	25,600	300	2,900	22,400
Nevada	59,500	600	10,200	48,700
Placer	213,000	1,900	36,600	175,000
Plumas	133,000	1,200	24,100	108,000
Sacramento	438,000	5,900	71,200	361,000
San Benito	24,200	300	3,000	20,900
San Joaquin	822,000	11,400	118,000	693,000
San Luis Obispo	5,200	100	600	4,500
Shasta	244,000	2,600	26,300	215,000
Sierra	47,400	600	11,500	35,300
Siskiyou	46,400	500	5,100	40,800
Solano	227,000	3,200	27,900	196,000
Stanislaus	567,000	7,900	78,000	481,000
Sutter	323,000	4,600	40,200	278,000
Tehama	223,000	3,200	26,100	194,000
Tulare	1,017,000	14,100	119,000	884,000
Tuolumne	49,100	700	7,800	40,600
Ventura	200	0	0	200
Yolo	389,000	5,500	46,600	337,000
Yuba	197,000	2,600	34,600	160,000
APPROXIMATE TOTALS, CENTRAL VALLEY AREA	11,750,000	166,000	1,547,000	10,040,000

An appreciable difference in the average precipitation between the northern and southern ends of the Central Valley has a profound effect on the requirement for irrigation water. Grain, for example, is successfully produced without irrigation in the Sacramento Valley, whereas irrigation is necessary throughout most of the San Joaquin River and Tulare Lake Basins. Temperature differences throughout the Central Valley Area also have an appreciable effect on the water requirement. The short, mild winters and long, warm growing seasons in the southern portion of the valley floor permit year-round production of crops. Potatoes and grain are grown during the winter, and diverse field and truck crops during the summer season. In the mountain valleys the short growing seasons generally limit crops to alfalfa or pasture. Table 113 presents the estimated unit values of mean seasonal consumptive use of applied irrigation water and of precipitation on lands devoted to crops of the various groups.

Unit mean seasonal consumptive use of applied water on farm lots was estimated to be about 0.5 foot of depth. Estimates of unit mean seasonal consumptive use of precipitation on farm lots varied from 0.5 foot to 2.0 feet in the various hydrographic units of the Central Valley Area, and averaged about 1.1 feet of depth. These estimates were employed for both present and probable ultimate conditions of development.

Urban and Suburban Water Use

Present unit seasonal values of use of water on urban and suburban water service areas of the Central Valley Area were estimated largely on the basis of available records of delivery of water to the areas, as compiled by municipalities and other public water service agencies. Probable ultimate values of water deliveries were estimated by applying to the present values derived percentage factors to account for expected future increase in population densities and in per capita water use. Table 114 presents the estimates of present and probable ultimate unit mean seasonal values of gross water deliveries to and consumptive use of water in urban and suburban water service areas.

Use of Water in Other Water Service Areas

Unit values of water use on the miscellany of service areas grouped in this category were derived generally from data on measured or estimated present deliveries of water to the typical development involved. In most cases the estimates were made in terms of per capita use of water, and the actual acreage of the service area was not a significant factor. In such cases the aggregate amount of water deliveries is relatively very small, and negligible recovery of return flow is involved. For purposes of study, therefore, the estimated unit values of delivery of water to these facilities were considered to be also the measures of consumptive use of applied water.

Both the National Forest and Park Services provided estimates of present and probable ultimate unit deliveries of water to all facilities within their jurisdiction. The estimates were generally in terms of per capita use of water, and were based on actual measurements and experience. They varied widely from place to place and in type of use, and for this reason are not detailed herein.

The value of unit use of water by military establishments was derived on a per capita basis, from available records of delivery of water, flow through sewage plants, and estimates of population of the camps involved. The average daily per capita use at McClellan Field near Sacramento in 1950-51 was approximately 190 gallons. It was assumed that this value will hold in the future.

TABLE 110

PROBABLE ULTIMATE PATTERN OF IRRIGATED CROPS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Rice	Cotton	Sugar beets	Hay and grain	Miscellaneous field crops	Approximate total
	Sacramento River Basin												
	Mountain Units												
1	Goose Lake	10,600	9,400	200	0	0	0	0	0	0	4,900	0	25,100
2	Pit River	18,000	172,000	200	0	0	300	0	0	0	94,900	61,000	346,000
3	McCloud River	0	12,400	0	0	0	0	0	0	0	9,200	0	21,600
4	Sacramento River above Shasta Dam	0	5,500	0	0	0	200	0	0	0	3,400	200	9,300
5	West Side, Shasta Dam to Cottonwood Creek	0	18,400	1,000	0	0	100	0	0	0	16,500	100	36,100
6	East Side, Cow Creek to Paynes Creek	1,000	53,100	600	0	0	0	0	0	0	35,600	0	90,300
7	Red Bluff to Thomes Creek	5,000	21,400	0	0	0	0	0	0	0	15,400	3,100	44,900
8	Antelope to Mud Creek	0	7,500	1,000	0	0	0	0	0	0	2,800	0	11,300
9	Stony Creek	2,000	21,000	0	0	0	0	0	0	0	11,800	10,100	44,900
10	Butte and Chico Creeks	0	8,100	2,500	0	0	0	0	0	0	5,800	0	16,400
11	Cortina Creek	2,000	14,000	1,000	0	0	0	0	0	0	14,400	13,600	45,000
12	Feather River	18,200	136,000	13,400	500	0	0	0	0	0	12,400	12,100	193,000
13	Yuba and Bear Rivers	0	71,400	11,200	0	1,000	0	0	0	0	41,000	10,400	135,000
14	Cache Creek	3,000	24,400	9,000	0	0	3,000	0	0	0	14,100	13,200	66,700
15	American River	0	38,200	25,200	0	5,000	0	0	0	0	17,700	5,700	91,800
16	Putah Creek	2,000	13,000	1,200	0	0	3,000	0	0	0	10,200	8,000	37,400
	Subtotals, Mountain Units	61,800	626,000	66,500	500	6,000	6,600	0	0	0	310,000	138,000	1,215,000
	Valley Units												
17	Anderson-Cottonwood	3,000	11,700	1,200	0	1,000	600	0	0	0	7,000	0	24,500
18	Tehama	22,200	17,900	6,500	0	0	0	0	0	0	15,000	26,100	87,700
19	Vina	10,000	16,000	21,000	0	0	1,000	0	0	1,000	13,700	9,000	71,700
20	Orland	35,000	12,000	9,000	2,000	5,000	400	7,000	10,100	0	11,000	29,000	120,000
21	Chico	5,000	10,000	18,000	0	0	1,000	20,000	0	5,000	8,800	11,100	78,900
22	Arbuckle	10,000	11,000	12,000	0	2,000	5,000	5,000	15,000	3,000	16,100	25,000	104,000
23	Colusa Trough	40,900	35,600	22,000	500	4,500	12,000	160,000	25,000	65,000	30,500	40,000	436,000
24	Feather River to Butte Slough	25,500	16,000	31,300	1,000	5,000	7,000	68,100	0	30,000	15,000	9,000	208,000
25	Yuba	4,000	7,000	26,000	0	4,500	4,000	10,000	0	0	3,900	5,000	64,400
26	Marysville-Sheridan	7,300	26,300	20,000	0	6,000	12,000	48,000	0	7,000	17,800	20,000	164,000
27	Woodland	30,000	10,000	14,100	0	4,500	12,000	33,000	0	29,700	11,200	12,300	157,000
28	Carmichael	15,100	36,000	9,000	0	15,600	7,000	26,000	0	14,400	38,300	34,100	196,000
29	Dixon	37,300	13,900	10,300	0	0	8,800	0	0	24,500	12,500	35,700	143,000
30	Yolo	19,000	11,000	6,500	0	4,000	10,000	61,000	0	20,000	8,200	10,000	153,000
	Subtotals, Valley Units	264,000	234,000	207,000	3,500	52,100	83,800	438,000	50,100	209,000	209,000	266,000	2,008,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	326,000	860,000	273,000	4,000	58,100	90,400	438,000	50,100	200,000	519,000	404,000	3,223,000
	Tulare Lake Basin												
	Mountain Units												
31	West Side, Kern County	2,000	1,800	0	0	2,000	1,000	0	0	0	3,200	0	10,000
32	Kern River and Tehachapi Mountains	20,300	40,800	6,200	0	13,000	13,000	0	33,900	0	29,200	3,000	159,000
33	Tule River	1,200	2,900	2,200	0	5,000	1,000	0	9,100	0	6,100	0	27,500
34	Kaweah River	3,500	3,300	2,000	0	0	1,000	0	0	0	3,900	0	13,700
35	Kings River	1,100	5,700	0	0	1,000	0	0	0	0	2,700	0	10,500
	Subtotals, Mountain Units	28,100	54,500	10,400	0	21,000	16,000	0	43,000	0	45,100	3,000	221,000
	Valley Units												
36	Antelope Plain	42,000	18,400	6,000	0	10,000	30,000	0	225,000	5,000	25,300	25,100	387,000
37	Kern	106,000	56,500	12,900	15,000	45,000	51,700	0	497,000	10,000	34,700	0	829,000
38	Earlimart	40,000	21,600	9,000	30,300	45,000	20,000	0	140,000	0	18,000	14,900	339,000
39	Visalia	55,000	11,700	38,000	34,700	50,000	10,800	0	125,000	0	21,200	20,000	366,000
40	Fresno-Hanford	70,000	20,600	75,000	20,000	234,000	12,000	10,000	310,000	8,000	36,900	66,200	863,000
41	Tulare Lake	15,000	22,700	0	0	0	5,600	10,000	130,000	5,600	12,200	14,800	216,000
	Subtotals, Valley Units	328,000	152,000	141,000	100,000	384,000	130,000	20,000	1,427,000	28,600	148,000	141,000	3,000,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	356,000	207,000	151,000	100,000	405,000	146,000	20,000	1,470,000	28,600	193,000	144,000	3,221,000

TABLE 110—Continued

PROBABLE ULTIMATE PATTERN OF IRRIGATED CROPS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Orchard	Citrus	Vineyard	Truck crops	Rice	Cotton	Sugar beets	Hay and grain	Miscellaneous field crops	Approximate total
	San Joaquin River Basin												
	Mountain Units												
42	Mount Diablo	2,000	900	2,600	0	1,000	2,000	0	0	0	1,000	1,000	10,500
43	Altamont to San Luis Creek	7,000	9,100	5,000	0	1,000	2,300	0	0	0	5,100	0	29,500
44	West Side, Los Banos Creek to Avenal Creek	2,000	9,000	4,000	0	5,000	2,000	0	10,000	0	10,500	1,000	43,500
45	San Joaquin River	0	4,900	0	0	0	0	0	0	0	0	0	4,900
46	Chowchilla-Fresno River	0	11,400	1,000	0	2,000	0	0	2,000	0	3,900	100	20,400
47	Merced River	0	25,100	2,000	0	2,000	0	0	1,000	0	4,500	0	34,600
48	Tuolumne River	0	16,800	8,000	0	3,000	0	0	0	0	2,900	1,000	31,700
49	Stanislaus River	0	12,200	2,200	0	3,100	0	0	0	0	2,100	1,100	20,700
50	Mokelumne-Calaveras Rivers	0	30,100	3,600	0	6,100	0	0	0	0	12,100	1,800	53,700
51	Cosumnes River	0	26,600	8,300	0	6,000	0	0	0	0	7,000	3,100	51,000
	Subtotals, Mountain Units	11,000	146,000	36,700	0	29,200	6,300	0	13,000	0	49,100	9,100	300,000
	Valley Units												
52	Antioch	15,900	3,000	14,800	0	2,000	6,500	5,000	0	4,600	2,700	4,000	58,500
53	Delta-Mendota	13,000	14,000	5,000	0	3,000	6,000	0	5,000	0	7,600	10,000	63,600
54	West Side, San Joaquin Valley	80,500	34,700	30,000	0	20,000	32,000	0	361,000	3,000	32,500	88,900	683,000
55	Madera	36,000	25,200	15,000	0	35,000	5,000	40,500	156,000	2,800	12,900	31,000	359,000
56	Merced	35,000	28,800	27,100	0	27,000	13,000	78,600	100,000	16,000	21,600	39,600	387,000
57	Los Banos	50,000	15,000	14,000	0	1,000	8,000	40,000	75,000	3,500	10,600	34,000	251,000
58	Modesto	51,000	42,000	25,000	0	36,000	15,800	20,400	30,900	9,800	26,500	68,500	326,000
59	Vernalis	23,300	6,000	6,000	0	1,000	13,000	5,000	0	4,000	3,100	10,900	72,300
60	Oakdale	21,500	15,000	50,500	0	25,000	10,000	15,000	0	3,000	7,000	35,500	183,000
61	Stockton	56,000	36,900	50,000	0	63,000	29,600	75,000	0	10,000	25,100	56,200	402,000
62	Ione	6,000	54,300	4,000	0	5,000	7,000	0	0	0	30,400	8,100	115,000
63	Sacramento-San Joaquin Delta	30,500	25,200	5,700	0	0	136,000	700	0	35,000	111,000	51,000	395,000
	Subtotals, Valley Units	419,000	300,000	247,000	0	218,000	282,000	280,000	728,000	91,700	291,000	438,000	3,295,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	430,000	446,000	284,000	0	247,000	288,000	280,000	741,000	91,700	340,000	447,000	3,595,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	1,112,000	1,513,000	708,000	104,000	710,000	524,000	738,000	2,261,000	320,000	1,052,000	995,000	10,040,000

The water requirement for milling of lumber was determined on the basis of units of production. It was estimated that the milling process uses one gallon of water per board-foot of lumber produced, that pulp processing requires 56,000 gallons per 1,000 board-feet of chips, and that the manufacture of fiberboard utilizes 2,300 gallons per 1,000 board-feet of material processed. In addition to the foregoing, the consumptive use of water by evaporation from logging ponds was estimated to be about 3 acre-feet per 10,000,000 board-feet of lumber produced.

The California Department of Fish and Game, the United States Fish and Wildlife Service, and private individuals operating duck clubs provided information on the quantity of water used for migratory waterfowl refuges and hunting clubs in the Central Valley Area. Federal and state refuges are operated throughout the year, and the estimated seasonal consumptive use of water is 3.0 acre-feet per acre. This figure was based on estimates of total applied water, which varied from 4.5 acre-feet to 6.0 acre-feet per acre per season. Most private clubs are operated only during the hunting season, and it was estimated that the mean seasonal consumptive use of applied water is 1.0 acre-foot per acre per year.

For other water service areas not encompassed by the foregoing specific types of water service, unit values of consumptive use of applied water under probable ultimate conditions of devlopment were assigned on a per capita basis. In such areas, sparse residential, industrial, and recreational development is expected in the future. For areas outside national forests, monuments, and military reservations, it was estimated that the ultimate population density will average about eight persons per square mile, and that per capita consumptive use of water will be about 70 gallons per day. In areas inside national forests, monuments, and military reservations the same per capita use estimates were made, but the population density was assumed to average about four persons per square mile. The period of water use was assumed to be of only three months' duration during the sum-

TABLE 111

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit		Inside national forests, monuments, and military reservations		Outside national forests, monuments, and military reservations		Approximate total
Reference number	Name	Above 3,000-foot elevation	Below 3,000-foot elevation	Above 3,000-foot elevation	Below 3,000-foot elevation	
	Sacramento River Basin					
	Mountain Units					
1	Goose Lake	222,000	0	12,400	0	234,000
2	Pit River	1,855,000	130,000	977,000	74,300	3,036,000
3	McCloud River	248,000	53,600	78,400	32,400	412,000
4	Sacramento River above Shasta Dam	155,000	27,400	69,100	132,000	383,000
5	West Side, Shasta Dam to Cottonwood Creek	144,000	22,000	91,800	516,000	774,000
6	East Side, Cow Creek to Paynes Creek	88,000	10,900	161,000	452,000	712,000
7	Red Bluff to Thomes Creek	131,000	15,900	4,100	332,000	483,000
8	Antelope to Mud Creek	161,000	78,300	43,000	234,000	516,000
9	Stony Creek	156,000	116,000	0	305,000	577,000
10	Butte and Chico Creeks	29,500	0	58,200	95,800	183,000
11	Cortina Creek	0	0	0	214,000	214,000
12	Feather River	1,553,000	95,800	314,000	177,000	2,140,000
13	Yuba and Bear Rivers	517,000	52,400	30,100	330,000	930,000
14	Cache Creek	52,200	65,800	4,400	531,000	653,000
15	American River	818,000	77,300	15,200	286,000	1,197,000
16	Putah Creek	0	0	700	360,000	361,000
	Subtotals, Mountain Units	6,130,000	745,000	1,859,000	4,071,000	12,800,000
	Valley Units					
17	Anderson-Cottonwood	0	0	0	5,900	5,900
18	Tehama	0	0	0	25,900	25,900
19	Vina	0	0	0	52,300	52,300
20	Orland	0	0	0	6,800	6,800
21	Chico	0	0	0	13,800	13,800
22	Arbuckle	0	0	0	5,900	5,900
23	Colusa Trough	0	0	0	70,200	70,200
24	Feather River to Butte Slough	0	0	0	94,900	94,900
25	Yuba	0	0	0	5,300	5,300
26	Marysville-Sheridan	0	0	0	13,400	13,400
27	Woodland	0	0	0	17,500	17,500
28	Carmichael	0	0	0	10,800	10,800
29	Dixon	0	0	0	49,900	49,900
30	Yolo	0	0	0	16,900	16,900
	Subtotals, Valley Units	0	0	0	389,000	389,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	6,130,000	745,000	1,859,000	4,460,000	13,190,000
	Tulare Lake Basin					
	Mountain Units					
31	West Side, Kern County	0	0	19,000	275,000	294,000
32	Kern River and Tehachapi Mountains	1,282,000	30,000	737,000	605,000	2,654,000
33	Tule River	185,000	23,000	25,600	200,000	434,000
34	Kaweah River	250,000	9,400	59,800	276,000	595,000
35	Kings River	872,000	83,700	12,200	206,000	1,174,000
	Subtotals, Mountain Units	2,589,000	146,000	854,000	1,562,000	5,151,000
	Valley Units					
36	Antelope Plain	0	0	0	247,000	247,000
37	Kern	0	0	0	175,000	175,000
38	Earlimart	0	0	0	36,800	36,800
39	Visalia	0	0	0	38,600	38,600
40	Fresno-Hanford	0	0	0	81,900	81,900
41	Tulare Lake	0	0	0	600	600
	Subtotals, Valley Units	0	0	0	580,000	580,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	2,589,000	146,000	854,000	2,142,000	5,731,000

TABLE 111—Continued

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit		Inside national forests, monuments, and military reservations		Outside national forests, monuments, and military reservations		Approximate total
Reference number	Name	Above 3,000-foot elevation	Below 3,000-foot elevation	Above 3,000-foot elevation	Below 3,000-foot elevation	
	San Joaquin River Basin					
	Mountain Units					
42	Mount Diablo	0	0	1,000	88,800	89,800
43	Altamont to San Luis Creek	0	0	4,000	445,000	449,000
44	West Side, Los Banos Creek to Avenal Creek	0	0	85,900	726,000	812,000
45	San Joaquin River	898,000	41,800	3,600	168,000	1,112,000
46	Chowchilla-Fresno Rivers	49,600	1,300	22,200	319,000	392,000
47	Merced River	483,000	41,800	15,300	359,000	899,000
48	Tuolumne River	770,000	36,100	17,300	168,000	991,000
49	Stanislaus River	486,000	31,200	1,300	159,000	678,000
50	Mokelumne-Calaveras Rivers	250,000	0	87,300	326,000	663,000
51	Cosumnes River	104,000	2,900	51,100	267,000	425,000
	Subtotals, Mountain Units	3,041,000	155,000	289,000	3,026,000	6,511,000
	Valley Units					
52	Antioch	0	0	0	13,600	13,600
53	Delta-Mendota	0	0	0	1,900	1,900
54	West Side, San Joaquin Valley	0	0	0	3,000	3,000
55	Madera	0	0	0	58,100	58,100
56	Merced	0	0	0	54,900	54,900
57	Los Banos	0	0	0	117,000	117,000
58	Modesto	0	0	0	59,200	59,200
59	Vernalis	0	0	0	3,400	3,400
60	Oakdale	0	0	0	36,800	36,800
61	Stockton	0	0	0	61,000	61,000
62	Ione	0	0	0	121,000	121,000
63	Sacramento-San Joaquin Delta	0	0	0	39,000	39,000
	Subtotals, Valley Units	0	0	0	569,000	569,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	3,041,000	155,000	289,000	3,595,000	7,080,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	11,760,000	1,046,000	3,002,000	10,200,000	26,010,000

mer for areas above 3,000 feet in elevation, while water service for areas below 3,000 feet in elevation was assumed to be throughout the year.

CONSUMPTIVE USE OF WATER

In general, estimates of the amounts of water consumptively used in the Central Valley Area were derived by applying appropriate unit values of water use to the service areas involved. The estimates represent the seasonal amount of consumptive use of water under mean conditions of water supply and climate. Table 115 presents estimates of present consumptive use of applied water and precipitation in areas having water service, and Table 116 presents corresponding estimates for probable ultimate conditions of development.

FACTORS OF WATER DEMAND

In addition to the amount of water consumptively used in a given service area, certain factors relating to the water requirements, such as necessary rates, times, and places of delivery of water, quality of water, losses of water, etc., have to be given consideration in the design of water development works. In the Central Valley Area the most important of these demand factors are associated with the supply of water for irrigation. Of secondary importance are those related to the supply of water for urban, suburban, recreational, hydroelectric power generation, and other uses. The demand factors most pertinent to design of works to meet water requirements of the Central Valley are discussed in the following sections.

Monthly Distribution of Water Demands

Within the season, the demand for irrigation water in the Central Valley Area generally varies from little or none during the winter rainy months to more than 15 per cent of the seasonal total during dry summer months. In a portion of the west side of the San Joaquin Valley, off-season potatoes require the greatest amounts of irrigation water during the winter period. Available data indicate that considerable variation in water demand also occurs with crop and soil types, as well as with latitude and elevation above sea level. Urban water demands, while sub-

TABLE 112

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS, CENTRAL VALLEY AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigable lands	Urban and suburban areas	Other water service areas	Approximate total
	Sacramento River Basin				
	Mountain Units				
1	Goose Lake	29,400	300	234,000	264,000
2	Pit River	400,000	3,900	3,036,000	3,440,000
3	McCloud River	25,100	1,400	412,000	438,000
4	Sacramento River above Shasta Dam	10,900	2,000	383,000	396,000
5	West Side, Shasta Dam to Cottonwood Creek	41,100	400	774,000	815,000
6	East Side, Cow Creek to Paynes Creek	105,000	1,500	712,000	819,000
7	Red Bluff to Thomes Creek	52,200	500	483,000	536,000
8	Antelope to Mud Creek	13,000	100	516,000	529,000
9	Stony Creek	52,700	500	577,000	630,000
10	Butte and Chico Creeks	19,400	1,200	183,000	204,000
11	Cortina Creek	52,400	500	214,000	267,000
12	Feather River	246,000	8,900	2,140,000	2,395,000
13	Yuba and Bear Rivers	166,000	6,000	930,000	1,102,000
14	Cache Creek	77,200	2,000	653,000	732,000
15	American River	110,000	6,400	1,197,000	1,313,000
16	Putah Creek	43,100	400	361,000	405,000
	Subtotals, Mountain Units	1,444,000	36,000	12,800,000	14,280,000
	Valley Units				
17	Anderson-Cottonwood	28,400	3,500	5,900	37,800
18	Tehama	101,000	2,200	25,900	129,000
19	Vina	82,300	1,800	52,300	136,000
20	Orland	137,000	1,400	6,800	145,000
21	Chico	91,300	5,400	13,800	111,000
22	Arbuckle	119,000	600	5,900	126,000
23	Colusa Trough	507,000	2,000	70,200	579,000
24	Feather River to Butte Slough	245,000	1,800	94,900	341,000
25	Yuba	74,200	2,400	5,300	81,900
26	Marysville-Sheridan	200,000	3,300	13,400	217,000
27	Woodland	180,000	3,500	17,500	201,000
28	Carmichael	236,000	60,000	10,800	307,000
29	Dixon	165,000	2,200	49,900	217,000
30	Yolo	180,000	500	16,900	197,000
	Subtotals, Valley Units	2,346,000	90,600	389,000	2,826,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	3,790,000	127,000	13,190,000	17,110,000
	Tulare Lake Basin				
	Mountain Units				
31	West Side, Kern County	11,700	100	294,000	306,000
32	Kern River and Tehachapi Mountains	181,000	1,800	2,654,000	2,837,000
33	Tule River	31,800	400	434,000	466,000
34	Kaweah River	15,800	200	595,000	611,000
35	Kings River	11,900	100	1,174,000	1,186,000
	Subtotals, Mountain Units	252,000	2,600	5,151,000	5,406,000
	Valley Units				
36	Antelope Plain	451,000	3,000	247,000	701,000
37	Kern	962,000	24,300	175,000	1,161,000
38	Earlimart	394,000	3,400	36,800	434,000
39	Visalia	419,000	10,600	38,600	469,000
40	Fresno-Hanford	1,005,000	38,200	81,900	1,125,000
41	Tulare Lake	254,000	1,600	600	256,000
	Subtotals, Valley Units	3,485,000	81,100	580,000	4,146,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	3,737,000	83,700	5,731,000	9,552,000
	San Joaquin River Basin				
	Mountain Units				
42	Mount Diablo	12,000	100	89,800	102,000
43	Altamont to San Luis Creek	33,800	300	449,000	483,000
44	West Side, Los Banos Creek to Avenal Creek	50,400	500	812,000	863,000
45	San Joaquin River	5,000	100	1,112,000	1,117,000
46	Chowchilla-Fresno Rivers	24,500	200	392,000	417,000
47	Merced River	44,600	800	899,000	944,000
48	Tuolumne River	37,900	2,700	991,000	1,032,000
49	Stanislaus River	26,100	1,000	678,000	705,000
50	Mokelumne-Calaveras Rivers	68,900	1,700	663,000	734,000
51	Cosumnes River	62,200	1,900	425,000	489,000
	Subtotals, Mountain Units	365,000	9,300	6,511,000	6,886,000
	Valley Units				
52	Antioch	67,200	13,600	13,600	94,400
53	Delta-Mendota	72,100	500	1,900	74,500
54	West Side, San Joaquin Valley	785,000	5,100	3,000	793,000
55	Madera	422,000	3,800	58,100	484,000
56	Merced	463,000	5,600	54,900	523,000
57	Los Banos	293,000	2,700	117,000	413,000
58	Modesto	384,000	8,500	59,200	452,000
59	Vernalis	82,100	600	3,400	86,100
60	Oakdale	214,000	3,200	36,800	254,000
61	Stockton	489,000	24,100	61,000	574,000
62	Ione	150,000	900	121,000	272,000
63	Sacramento-San Joaquin Delta	439,000	2,900	39,000	481,000
	Subtotals, Valley Units	3,860,000	71,500	569,000	4,501,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	4,225,000	80,800	7,080,000	11,390,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	11,750,000	292,000	26,010,000	38,050,000

TABLE 113

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, CENTRAL VALLEY AREA

(In feet of depth)

Hydrographic unit		Alfalfa			Pasture			Orchard			Citrus			Vineyard			Cotton		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
	Sacramento River Basin																		
	Mountain Units																		
1	Goose Lake	1.7	1.1	2.8	1.8	1.0	2.8	1.2	1.1	2.3	-----	-----	-----	-----	-----	-----	-----	-----	-----
2	Pit River	1.4	1.6	3.0	1.6	1.4	3.0	0.8	1.5	2.3	-----	-----	-----	-----	-----	2.3	-----	-----	-----
3	McCloud River	-----	-----	-----	1.5	1.7	3.2	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----	-----
4	Sacramento River above Shasta Dam	1.4	1.9	3.3	1.7	1.6	3.3	0.9	1.6	2.5	-----	-----	-----	-----	-----	-----	-----	-----	-----
5	West Side, Shasta Dam to Cottonwood Creek	-----	-----	-----	2.5	1.5	4.0	1.4	1.6	3.0	-----	-----	-----	-----	-----	-----	-----	-----	-----
6	East Side, Cow Creek to Paynes Creek	2.0	1.7	3.7	2.2	1.5	3.7	1.4	1.5	2.9	-----	-----	-----	-----	-----	-----	-----	-----	-----
7	Red Bluff to Thomes Creek	2.4	1.5	3.9	2.6	1.3	3.9	1.5	1.4	2.9	-----	-----	-----	-----	-----	-----	-----	-----	-----
8	Antelope to Mud Creek	-----	-----	-----	1.5	1.6	3.1	0.7	1.7	2.4	-----	-----	-----	-----	-----	-----	-----	-----	-----
9	Stony Creek	2.3	1.5	3.8	2.6	1.2	3.8	1.6	1.3	2.9	-----	-----	-----	-----	-----	-----	-----	-----	-----
10	Butte and Chico Creeks	1.4	2.2	3.6	1.7	1.9	3.6	0.9	1.8	2.7	-----	-----	-----	-----	-----	-----	-----	-----	-----
11	Cortina Creek	2.4	1.4	3.8	2.6	1.2	3.8	1.6	1.3	2.9	-----	-----	-----	-----	-----	-----	-----	-----	-----
12	Feather River	1.8	1.4	3.2	2.1	1.4	3.5	2.0	1.5	3.5	2.1	1.3	3.4	-----	-----	-----	-----	-----	-----
13	Yuba and Bear Rivers	-----	-----	-----	2.2	1.3	3.5	1.3	1.4	2.7	1.4	1.2	2.6	0.9	1.2	2.1	-----	-----	-----
14	Cache Creek	2.0	1.6	3.6	2.3	1.3	3.6	1.3	1.4	2.7	-----	-----	-----	-----	-----	-----	-----	-----	-----
15	American River	-----	-----	-----	2.1	1.3	3.4	1.3	1.3	2.6	-----	-----	-----	1.0	1.2	2.2	-----	-----	-----
16	Putah Creek	2.0	1.6	3.6	2.3	1.3	3.6	1.3	1.5	2.8	-----	-----	-----	-----	-----	-----	-----	-----	-----
	Valley Units																		
17	Anderson-Cottonwood	2.2	1.8	4.0	2.5	1.5	4.0	1.4	1.6	3.0	-----	-----	-----	0.9	1.4	2.3	-----	-----	-----
18	Tehama	2.4	1.6	4.0	2.7	1.3	4.0	1.7	1.3	3.0	1.8	1.2	3.0	1.2	1.2	2.4	-----	-----	-----
19	Vina	2.3	1.6	3.9	2.5	1.4	3.9	1.5	1.4	2.9	-----	-----	-----	-----	-----	-----	-----	-----	-----
20	Orland	2.6	1.4	4.0	2.7	1.3	4.0	1.7	1.3	3.0	1.8	1.2	3.0	1.2	1.2	2.4	1.4	1.1	2.5
21	Chico	2.3	1.6	3.9	2.6	1.3	3.9	1.6	1.4	3.0	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
22	Arbuckle	2.4	1.4	3.8	2.6	1.2	3.8	1.6	1.3	2.9	-----	-----	-----	1.2	1.1	2.3	1.4	1.0	2.4
23	Colusa Trough	2.5	1.3	3.8	2.6	1.2	3.8	1.7	1.2	2.9	1.9	1.0	2.9	1.3	1.0	2.3	1.4	1.0	2.4
24	Feather River to Butte Slough	2.3	1.6	3.9	2.6	1.3	3.9	1.6	1.3	2.9	1.7	1.2	2.9	1.1	1.2	2.3	-----	-----	-----
25	Yuba	2.5	1.4	3.9	2.6	1.3	3.9	1.6	1.3	2.9	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
26	Marysville-Sheridan	2.3	1.6	3.9	2.6	1.3	3.9	1.6	1.3	2.9	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
27	Woodland	2.5	1.4	3.9	2.7	1.2	3.9	1.6	1.3	2.9	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
28	Carmichael	2.3	1.4	3.7	2.5	1.2	3.7	1.5	1.3	2.8	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
29	Dixon	2.4	1.4	3.8	2.6	1.2	3.8	1.6	1.3	2.9	1.7	1.1	2.8	1.2	1.1	2.3	-----	-----	-----
30	Yolo	2.4	1.3	3.7	2.5	1.2	3.7	1.5	1.3	2.8	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
	Tulare Lake Basin																		
	Mountain Units																		
31	West Side, Kern County	3.1	0.6	3.7	3.1	0.6	3.7	-----	-----	-----	-----	-----	-----	2.5	0.6	3.1	-----	-----	-----
32	Kern River and Tehachapi Mountains	3.3	0.7	4.0	3.3	0.7	4.0	2.3	0.7	3.0	2.3	0.7	3.0	2.5	0.7	3.2	2.2	0.7	2.9
33	Tule River	3.1	0.8	3.9	3.1	0.8	3.9	2.1	0.8	2.9	2.1	0.8	2.9	1.5	0.8	2.3	2.0	0.8	2.8
34	Kaweah River	2.7	1.2	3.9	2.7	1.2	3.9	1.7	1.2	2.9	1.7	1.2	2.9	-----	-----	-----	-----	-----	-----
35	Kings River	3.1	0.7	3.8	3.1	0.7	3.8	2.2	0.7	2.9	-----	-----	-----	1.5	0.7	2.2	-----	-----	-----
	Valley Units																		
36	Antelope Plain	3.1	0.5	3.6	3.1	0.5	3.6	2.3	0.5	2.8	-----	-----	-----	2.5	0.5	3.0	2.3	0.5	2.8
37	Kern	3.1	0.5	3.6	3.1	0.5	3.6	2.3	0.5	2.8	2.3	0.5	2.8	2.5	0.5	3.0	2.3	0.5	2.8
38	Earlimart	2.9	0.7	3.6	2.9	0.7	3.6	2.1	0.7	2.8	2.1	0.7	2.8	2.3	0.7	3.0	2.1	0.7	2.8
39	Visalia	2.9	0.9	3.8	2.9	0.9	3.8	2.0	0.9	2.9	2.0	0.9	2.9	2.2	0.9	3.1	1.9	0.9	2.8
40	Fresno-Hanford	2.8	0.7	3.5	2.8	0.7	3.5	2.1	0.7	2.8	2.1	0.7	2.8	2.2	0.7	2.9	2.0	0.7	2.7
41	Tulare Lake	2.9	0.5	3.4	2.9	0.5	3.4	-----	-----	-----	-----	-----	-----	-----	-----	-----	2.2	0.5	2.7

TABLE 113—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, CENTRAL VALLEY AREA

(In feet of depth)

Hydrographic unit		Alfalfa			Pasture			Orchard			Citrus			Vineyard			Cotton		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
	San Joaquin River Basin																		
	Mountain Units																		
42	Mount Diablo	2.6	1.2	3.8	2.7	1.1	3.8	1.7	1.2	2.9	-----	-----	-----	1.2	1.1	2.3	-----	-----	-----
43	Altamont to San Luis Creek	2.9	0.8	3.7	2.9	0.8	3.7	2.0	0.8	2.8	-----	-----	-----	-----	-----	-----	-----	-----	-----
44	West Side, Los Banos Creek to Avenal Creek	2.9	0.8	3.7	2.9	0.8	3.7	2.0	0.8	2.8	-----	-----	-----	2.4	0.8	3.2	2.3	0.8	3.1
45	San Joaquin River	-----	-----	-----	2.5	1.1	3.6	1.5	1.2	2.7	-----	-----	-----	-----	-----	-----	-----	-----	-----
46	Chowchilla-Fresno Rivers	-----	-----	-----	2.7	1.1	3.8	1.7	1.2	2.9	-----	-----	-----	1.2	1.0	2.2	1.9	1.1	3.0
47	Merced River	-----	-----	-----	2.2	1.3	3.5	1.4	1.2	2.6	-----	-----	-----	1.0	1.2	2.2	1.7	1.4	3.1
48	Tuolumne River	-----	-----	-----	2.3	1.5	3.8	1.3	1.5	2.8	-----	-----	-----	0.9	1.4	2.3	-----	-----	-----
49	Stanislaus River	-----	-----	-----	2.6	1.2	3.8	1.3	0.7	2.0	-----	-----	-----	1.2	1.1	2.3	-----	-----	-----
50	Mokelumne-Calaveras Rivers	-----	-----	-----	2.5	1.4	3.9	1.5	1.4	2.9	-----	-----	-----	1.1	1.2	2.3	-----	-----	-----
51	Cosumnes River	-----	-----	-----	1.9	1.6	3.5	1.1	1.6	2.7	-----	-----	-----	0.9	1.3	2.2	-----	-----	-----
	Valley Units																		
52	Antioch	2.8	0.9	3.7	2.8	0.9	3.7	1.9	0.9	2.8	-----	-----	-----	1.4	0.9	2.3	-----	-----	-----
53	Delta-Mendota	2.9	0.8	3.7	2.9	0.8	3.7	2.1	0.8	2.9	-----	-----	-----	1.5	0.8	2.3	1.6	0.8	2.4
54	West Side, San Joaquin Valley	3.1	0.5	3.6	3.1	0.5	3.6	2.3	0.5	2.8	-----	-----	-----	2.5	0.5	3.0	2.3	0.5	2.8
55	Madera	2.9	0.8	3.7	2.9	0.8	3.7	2.0	0.8	2.8	2.0	0.8	2.8	2.1	0.8	2.9	1.7	0.8	2.5
56	Merced	2.8	1.0	3.8	2.8	1.0	3.8	1.9	1.0	2.9	-----	-----	-----	1.3	1.0	2.3	1.4	1.0	2.4
57	Los Banos	3.0	0.7	3.7	3.0	0.7	3.7	2.1	0.7	2.8	-----	-----	-----	1.6	0.7	2.3	1.7	0.7	2.4
58	Modesto	2.7	1.0	3.7	2.7	1.0	3.7	1.8	1.0	2.8	-----	-----	-----	1.2	1.0	2.2	1.4	1.0	2.4
59	Vernalis	2.9	0.9	3.8	2.9	0.9	3.8	2.0	0.9	2.9	-----	-----	-----	1.4	0.9	2.3	-----	-----	-----
60	Oakdale	2.6	1.1	3.7	2.6	1.1	3.7	1.7	1.1	2.8	-----	-----	-----	1.2	1.1	2.3	-----	-----	-----
61	Stockton	2.4	1.3	3.7	2.5	1.2	3.7	1.5	1.3	2.8	-----	-----	-----	1.2	1.1	2.3	-----	-----	-----
62	Ione	2.6	1.1	3.7	2.7	1.0	3.7	1.8	1.1	2.9	1.8	1.1	2.9	1.2	1.1	2.3	-----	-----	-----
63	Sacramento-San Joaquin Delta	2.4	1.1	3.5	2.6	0.9	3.5	1.4	1.1	2.5	-----	-----	-----	-----	-----	-----	-----	-----	-----

Hydrographic unit		Rice			Truck crops			Hay and grain			Miscellaneous field crops			Sugar beets		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
	Sacramento River Basin															
	Mountain Units															
1	Goose Lake	-----	-----	-----	0.5	1.1	1.6	1.0	1.0	2.0	0.6	1.1	1.7	-----	-----	-----
2	Pit River	-----	-----	-----	0.4	1.2	1.6	0.7	1.2	1.9	0.5	1.2	1.7	-----	-----	-----
3	McCloud River	-----	-----	-----	0.4	1.3	1.7	0.8	1.3	2.1	-----	-----	-----	-----	-----	-----
4	Sacramento River above Shasta Dam	-----	-----	-----	0.5	1.2	1.7	1.0	1.1	2.1	0.6	1.2	1.8	-----	-----	-----
5	West Side, Shasta Dam to Cottonwood Creek	-----	-----	-----	0.8	1.2	2.0	0.4	1.3	1.7	0.9	1.2	2.1	-----	-----	-----
6	East Side, Cow Creek to Paynes Creek	-----	-----	-----	0.8	1.2	2.0	0.7	1.2	1.9	-----	-----	-----	-----	-----	-----
7	Red Bluff to Thomes Creek	-----	-----	-----	-----	-----	-----	0.5	1.2	1.7	1.0	1.2	2.2	-----	-----	-----
8	Antelope to Mud Creek	-----	-----	-----	-----	-----	-----	0.3	1.3	1.6	-----	-----	-----	-----	-----	-----
9	Stony Creek	-----	-----	-----	-----	-----	-----	0.5	1.2	1.7	1.0	1.0	2.0	-----	-----	-----
10	Butte and Chico Creeks	-----	-----	-----	0.5	1.5	2.0	0.3	1.7	2.0	-----	-----	-----	-----	-----	-----
11	Cortina Creek	-----	-----	-----	-----	-----	-----	0.7	1.1	1.8	1.0	1.1	2.1	-----	-----	-----
12	Feather River	-----	-----	-----	-----	-----	-----	0.3	1.1	1.4	0.8	1.2	2.0	-----	-----	-----
13	Yuba and Bear Rivers	-----	-----	-----	0.8	1.1	1.9	0.8	1.0	1.8	1.0	1.1	2.1	-----	-----	-----
14	Cache Creek	-----	-----	-----	0.8	1.1	1.9	0.5	1.1	1.6	0.8	1.2	2.0	-----	-----	-----
15	American River	-----	-----	-----	-----	-----	-----	0.6	1.1	1.7	0.9	1.1	2.0	-----	-----	-----
16	Putah Creek	-----	-----	-----	0.7	1.1	1.8	0.4	1.2	1.6	0.7	1.2	1.9	-----	-----	-----

TABLE 113—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, CENTRAL VALLEY AREA

(In feet of depth)

Hydrographic unit		Rice			Truck crops			Hay and grain			Miscellaneous field crops			Sugar beets		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
	Sacramento River Basin—Continued															
	Valley Units															
17	Anderson-Cottonwood				0.8	1.2	2.0	0.4	1.3	1.7	0.9	1.3	2.2			
18	Tehama				0.9	1.1	2.0	0.6	1.1	1.7	1.0	1.1	2.1			
19	Vina				0.8	1.1	1.9	0.5	1.2	1.7	1.0	1.1	2.1	1.5	1.2	2.7
20	Orland	4.1	1.1	5.2	0.9	1.1	2.0	0.6	1.1	1.7	1.0	1.1	2.1			
21	Chico	4.1	1.1	5.2	0.8	1.1	1.9	0.5	1.2	1.7	1.0	1.1	2.1	1.6	1.1	2.7
22	Arbuckle	4.1	1.0	5.1	0.9	1.0	1.9	0.5	1.1	1.6	1.0	1.0	2.0	1.5	1.1	2.6
23	Colusa Trough	4.1	1.0	5.1	0.9	1.0	1.9	0.6	1.0	1.6	1.0	1.0	2.0	1.6	1.0	2.6
24	Feather River to Butte Slough	4.1	1.1	5.2	0.8	1.1	1.9	0.6	1.1	1.7	1.0	1.1	2.1	1.6	1.1	2.7
25	Yuba	4.1	1.0	5.1	0.9	1.0	1.9	0.7	1.0	1.7	1.1	1.0	2.1	1.3	1.1	2.4
26	Marysville-Sheridan	4.1	1.1	5.2	0.8	1.1	1.9	0.6	1.1	1.7	1.0	1.1	2.1	1.6	1.1	2.7
27	Woodland	4.1	1.0	5.1	0.9	1.0	1.9	0.5	1.1	1.6	1.0	1.0	2.0	1.6	1.1	2.7
28	Carmichael	4.1	1.0	5.1	0.8	1.0	1.8	0.5	1.1	1.6	1.0	1.0	2.0	1.5	1.1	2.6
29	Dixon				0.9	1.0	1.9	0.5	1.1	1.6	1.0	1.0	2.0	1.6	1.1	2.7
30	Yolo	4.1	1.1	5.2	0.7	1.1	1.8	0.5	1.1	1.6	0.9	1.1	2.0	1.5	1.1	2.6
	Tulare Lake Basin															
	Mountain Units															
31	West Side, Kern County				1.1	0.6	1.7	0.7	0.6	1.3						
32	Kern River and Tehachapi Mountains				0.9	0.7	1.6	0.6	0.7	1.3	1.5	0.7	2.2			
33	Tule River				1.2	0.8	2.0	1.3	0.8	2.1						
34	Kaweah River				0.8	1.1	1.9	0.9	1.1	2.0						
35	Kings River							1.3	0.7	2.0						
	Valley Units															
36	Antelope Plain				1.0	0.5	1.5	0.8	0.5	1.3	1.6	0.5	2.1	2.0	0.5	2.5
37	Kern				1.0	0.5	1.5	0.8	0.5	1.3	1.5	0.5	2.0	2.0	0.5	2.5
38	Earlimart				0.5	0.7	1.2	0.6	0.7	1.3	1.3	0.7	2.0	1.8	0.7	2.5
39	Visalia				0.7	0.9	1.6	0.5	0.9	1.4	1.2	0.9	2.1	1.6	0.9	2.5
40	Fresno-Hanford	4.1	0.7	4.8	0.8	0.7	1.5	0.6	0.7	1.3	1.3	0.7	2.0	1.7	0.7	2.4
41	Tulare Lake	4.1	0.5	4.6	1.0	0.5	1.5	0.8	0.5	1.3	1.5	0.5	2.0	1.9	0.5	2.4
	San Joaquin River Basin															
	Mountain Units															
42	Mount Diablo				0.7	1.1	1.8	0.3	1.1	1.4	0.9	1.1	2.0			
43	Altamont to San Luis Creek				0.8	0.8	1.6	0.3	0.8	1.1						
44	West Side, Los Banos Creek to Avenal Creek				0.7	0.8	1.5	0.5	0.8	1.3	1.2	0.8	2.0			
45	San Joaquin River															
46	Chowchilla-Fresno Rivers				0.8	1.1	1.9	0.9	1.1	2.0	0.9	1.1	2.0			
47	Merced River				0.6	1.3	1.9	0.7	1.3	2.0						
48	Tuolumne River				0.6	1.3	1.9	0.8	1.2	2.0	0.8	1.2	2.0			
49	Stanislaus River							1.3	0.7	2.0	1.7	1.2	2.9			
50	Mokelumne-Calaveras Rivers							0.9	1.2	2.1	0.9	1.2	2.1			
51	Cosumnes River							0.6	1.3	1.9	0.6	1.3	1.9			
	San Joaquin River Basin															
	Valley Units															
52	Antioch	4.1	0.9	5.0	0.9	0.9	1.8	0.4	0.9	1.3	1.1	0.9	2.0	1.7	0.9	2.6
53	Delta-Mendota				1.0	0.8	1.8	0.5	0.8	1.3	1.2	0.8	2.0	1.8	0.8	2.6
54	West Side, San Joaquin Valley	4.1	0.5	4.6	1.0	0.5	1.5	1.2	0.5	1.7	1.5	0.5	2.0	2.0	0.5	2.5
55	Madera	4.1	0.8	4.9	1.0	0.8	1.8	0.5	0.8	1.3	1.2	0.8	2.0	1.8	0.8	2.6
56	Merced	4.1	1.0	5.1	0.8	1.0	1.8	0.4	1.0	1.4	1.0	1.0	2.0	1.6	1.0	2.6
57	Los Banos	4.1	0.7	4.8	1.1	0.7	1.8	0.6	0.7	1.3	1.3	0.7	2.0	1.9	0.7	2.6
58	Modesto	4.1	1.0	5.1	0.8	1.0	1.8	0.4	1.0	1.4	1.0	1.0	2.0	1.6	1.0	2.6
59	Vernalis	4.1	0.9	5.0	0.9	0.9	1.8	0.5	0.9	1.4	1.2	0.9	2.1	1.8	0.9	2.7
60	Oakdale	4.1	1.1	5.2	0.7	1.1	1.8	0.3	1.1	1.4	0.9	1.1	2.0	1.5	1.1	2.6
61	Stockton	4.1	1.2	5.3	0.9	0.9	1.8	0.3	1.3	1.6	0.8	1.2	2.0	1.4	1.2	2.6
62	Ione				0.8	1.1	1.9	0.4	1.1	1.5	1.0	1.1	2.1			
63	Sacramento-San Joaquin Delta	4.1	1.1	5.2	1.5	1.0	2.5	1.5	1.1	2.6	2.0	0.9	2.9	1.7	1.1	2.8

stantially higher in summer than in winter months, are far more uniform throughout the season than are those for irrigation. They vary from four to six per cent of the seasonal total during the months of December through March, to over 10 per cent from June through September. Representative data on monthly distribution of irrigation and urban water demands in the Central Valley Area are presented in Table 117.

Irrigation Water Service Area Efficiency

In the study of irrigation water requirements of the Central Valley Area it was found to be desirable to estimate the over-all efficiency of irrigation practice in the various service areas. Irrigation water service area efficiency was measured by the ratio of consumptive use of applied irrigation water to the gross amount of irrigation water delivered to a service area. Present irrigation water service area efficiencies were estimated after consideration of geologic conditions of the service areas involved, their topographic position in relation to sources of water supply and to other service areas, consumptive use of water, irrigation efficiency, usable return flow, and urban and suburban sewage outflow.

Extensive data concerning present irrigation practices in the Central Valley Area are available, and provided the basis for the estimates of water service area efficiencies which were formulated during the current study. Data on seasonal quantities of surface water diverted by present water service agencies are available from records maintained by these agencies, and from data compiled by the Sacramento-San Joaquin Water Supervision, an activity of the State Division of Water Resources. Irrigation efficiencies were computed by comparing recorded surface diversions of water with calculated consumptive use values for the areas served by various operating agencies. It was indicated that the irrigation efficiencies range from 40 to 65 per cent for most areas on the valley floor, and are about 50 per cent in the areas lying at higher elevations.

Studies conducted by the Division of Water Resources in Sutter and Yuba Counties and in San Joaquin County resulted in the conclusion that irrigation efficiencies are somewhat higher when water supplies are obtained by pumping from ground water storage. In the Sutter-Yuba area during 1947-1948 the irrigation efficiency was approximately 48 per cent. In San Joaquin County the average irrigation efficiency attained with water supplies obtained from ground water during the 1948-49 season was approximately 52 per cent. Data available from records of power consumption by agricultural loads in the west side of the San Joaquin Valley in Fresno and Merced Counties, for 1948-49, indicate that the average irrigation efficiency was approximately 60 per cent.

As a result of the analysis, irrigation water service area efficiencies for various portions of the Central Valley Area under present conditions were found to range from 40 to 90 per cent, with the higher efficiencies occurring in areas principally supplied by development of the ground water resources. It was estimated that ultimate efficiencies would be somewhat higher, as a result of anticipated improved agricultural technology. Additional factors affecting the estimates of probable ultimate irrigation water service area efficiencies were related to the location and extent of presently undeveloped irrigable lands, as well as the increased costs of water development. For purposes of illustration, the weighted mean values of all irrigation water service area efficiencies within each hydrographic unit of the Central Valley Area are presented in Table 118.

WATER REQUIREMENTS

As the term is used in this bulletin, water requirements refer to the amounts of water needed to provide for all beneficial uses of water and for irrecoverable losses incidental to such uses. Those water requirements of the Central Valley Area that are primarily nonconsumptive in nature are discussed in general terms in the ensuing section. Following this, water requirements that are consumptive in nature are evaluated, both for present and for probable ultimate conditions of development.

Requirements of a Nonconsumptive Nature

The principal water requirements of a nonconsumptive nature in the Central Valley Area are associated with the preservation and propagation of fish and wildlife, flood control, salinity repulsion from the delta, navigation, and hydroelectric power. For the most part, such requirements for water are extremely difficult to evaluate other than in conjunction with definite plans for water resource development. Their consideration in this bulletin, therefore, is limited to discussion of their implications as related to planning for future development of water resources.

Fish and Wildlife. The Central Valley Area is of primary importance to hunting and fishing in California. The spawning areas in the streams and the numerous wild fowl refuges also contribute greatly to the maintenance of these sports throughout the Pacific Coast. A significant contribution to the economy of the State is made through expenditures by fishermen and hunters, and through returns to commercial fisheries. The recreational resources of the area are particularly attractive to residents of crowded metropolitan areas, many of whom come to the Central Valley Area for hunting, fishing, and general recreation. Most of the many species of fish and game present in California can be found in this area.

TABLE 114

ESTIMATED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY AND CONSUMPTIVE USE OF WATER IN URBAN AND SUBURBAN AREAS, CENTRAL VALLEY AREA

(In feet of depth)

Hydrographic unit		Present		Probable ultimate	
Reference number	Name	Gross delivery	Consumptive use of applied water	Gross delivery	Consumptive use of applied water
	Sacramento River Basin				
	Mountain Units				
1	Goose Lake	0.7	0.4	1.8	0.9
2	Pit River	0.7	0.4	1.8	0.9
3	McCloud River	0.7	0.4	1.8	0.9
4	Sacramento River above Shasta Dam	0.7	0.4	1.8	0.9
5	West Side, Shasta Dam to Cottonwood Creek	0.7	0.4	2.4	1.2
6	East Side, Cow Creek to Paynes Creek	0.7	0.4	2.4	1.2
7	Red Bluff to Thomes Creek	0	0	2.6	1.3
8	Antelope to Mud Creek	0	0	2.4	1.2
9	Stony Creek	0.9	0.5	2.6	1.3
10	Butte and Chico Creeks	0.9	0.5	2.2	1.1
11	Cortina Creek	0	0	2.6	1.3
12	Feather River	1.3	0.7	1.8	0.9
13	Yuba and Bear Rivers	0.5	0.3	2.4	1.2
14	Cache Creek	0.5	0.3	2.4	1.2
15	American River	0.8	0.4	2.4	1.2
16	Putah Creek	0.8	0.4	2.4	1.2
	Valley Units				
17	Anderson-Cottonwood	1.6	0.8	2.8	1.4
18	Tehama	1.2	0.6	2.8	1.4
19	Vina	0.7	0.4	2.8	1.4
20	Orland	0.9	0.5	2.8	1.4
21	Chico	0.8	0.4	2.8	1.4
22	Arbuckle	2.6	1.3	2.6	1.3
23	Colusa Trough	1.3	0.7	2.6	1.3
24	Feather River to Butte Slough	0.9	0.5	2.8	1.4
25	Yuba	1.4	0.7	2.6	1.3
26	Marysville-Sheridan	0.7	0.4	2.6	1.3
27	Woodland	1.5	0.8	2.6	1.3
28	Carmichael	1.0	0.5	2.4	1.2
29	Dixon	1.2	0.6	2.4	1.2
30	Yolo	0.7	0.4	2.4	1.2
	Tulare Lake Basin				
	Mountain Units				
31	West Side, Kern County	0	0	2.8	1.4
32	Kern River and Tehachapi Mountains	0.8	0.4	2.6	1.3
33	Tule River	0.8	0.4	2.6	1.3
	Mountain Units—Continued				
34	Kaweah River	0.8	0.4	2.6	1.3
35	Kings River	0	0	2.6	1.3
	Valley Units				
36	Antelope Plain	0.8	0.4	2.8	1.4
37	Kern	1.8	0.9	2.8	1.4
38	Earlimart	2.2	1.1	2.8	1.4
39	Visalia	2.2	1.1	2.8	1.4
40	Fresno-Hanford	2.5	1.3	2.8	1.4
41	Tulare Lake	2.8	1.4	2.8	1.4
	San Joaquin River Basin				
	Mountain Units				
42	Mount Diablo	0	0	2.6	1.3
43	Altamont to San Luis Creek	0	0	2.6	1.3
44	West Side, Los Banos Creek to Avenal Creek	0.7	0.4	2.6	1.3
45	San Joaquin River	0.8	0.4	2.4	1.2
46	Chowchilla-Fresno Rivers	0.9	0.5	2.6	1.3
47	Merced River	0.8	0.4	2.6	1.3
48	Tuolumne River	0.8	0.4	2.6	1.3
49	Stanislaus River	0.9	0.5	2.6	1.3
50	Mokelumne-Calaveras Rivers	0.5	0.3	2.6	1.3
51	Cosumnes River	0.5	0.3	2.4	1.2
	Valley Units				
52	Antioch	1.9	1.0	2.6	1.3
53	Delta-Mendota	0.7	0.4	2.8	1.4
54	West Side, San Joaquin Valley	0.1	0.1	2.8	1.4
55	Madera	2.5	1.3	2.6	1.3
56	Merced	1.6	0.8	2.6	1.3
57	Los Banos	1.3	0.7	2.8	1.4
58	Modesto	2.0	1.0	2.6	1.3
59	Vernalis	1.1	0.6	2.8	1.4
60	Oakdale	1.0	0.5	2.6	1.3
61	Stockton	1.9	1.0	2.4	1.2
62	Ione	0.6	0.3	2.4	1.2
63	Sacramento-San Joaquin Delta	1.3	0.7	2.4	1.2

The anadromous fishes found in the Central Valley Area include striped bass, king salmon, steelhead, shad, and sturgeon. A major portion of their lives is spent in the ocean, although they return to fresh water to spawn. With the exception of steelhead, the bulk of the anadromous fishes of the State is produced in the Sacramento-San Joaquin river system. Virtually all of the striped bass caught in California are produced in this area, as are 70 per cent of the salmon. In addition, salmon from the Central Valley Area are caught at sea along the coasts of Oregon, Washington, and British Columbia. The California Department of Fish and Game estimates the minimum annual value of these anadromous fishes to be $27,500,000 in the Central Valley Area, based upon sportsmen's expenditures and receipts of commercial fishermen.

The fishery for these species is concentrated in the Delta area, and in that portion of the Sacramento River and its tributaries that lie in the valley or low foothills. The San Joaquin River and its tributaries, once of great importance to salmon spawning, are of little value to these fisheries at the present time due to insufficient stream flow.

Trout provide the principal form of angling in the numerous streams and lakes of the mountainous portions of the Central Valley Area. Rainbow trout are the most numerous, but eastern brook trout are plentiful at higher elevations. Golden trout, the California State fish, are found in the high lakes and streams from Yosemite National Park south through the Kern River. Brown trout are also taken in many streams and lakes in the area, particularly those at lower elevations.

The lakes, streams, and reservoirs of the foothill areas and of the valley support populations of black bass, crappies, catfish, and other warm-water fishes. Clear Lake, in Lake County, and the Sacramento-San

TABLE 115

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, CENTRAL VALLEY AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Unclassified areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
	Sacramento River Basin						
	Mountain Units						
1	Goose Lake	10,800	8,300	100	0	0	10,900
2	Pit River	109,000	136,000	600	500	1,000	111,000
3	McCloud River	2,800	3,200	0	300	100	3,200
4	Sacramento River above Shasta Dam	2,400	2,400	0	400	200	3,000
5	West Side, Shasta Dam to Cottonwood Creek	2,400	2,300	0	100	100	2,600
6	East Side Cow Creek to Paynes Creek	8,200	6,400	0	300	600	9,100
7	Red Bluff to Thomes Creek	0	0	0	0	300	300
8	Antelope to Mud Creek	1,600	2,500	0	0	200	1,800
9	Stony Creek	1,100	600	0	0	300	1,400
10	Butte and Chico Creeks	2,000	3,800	0	300	100	2,400
11	Cortina Creek	0	0	0	0	0	0
12	Feather River	88,700	104,000	600	3,800	3,500	96,600
13	Yuba and Bear Rivers	42,300	30,100	200	1,300	1,900	45,700
14	Cache Creek	13,900	11,900	100	300	200	14,500
15	American River	35,300	33,300	200	1,300	800	37,600
16	Putah Creek	4,700	4,500	0	100	0	4,800
	Subtotals, Mountain Units	325,000	349,000	1,800	8,700	9,300	345,000
	Valley Units						
17	Anderson-Cottonwood	40,100	25,700	100	2,000	0	42,200
18	Tehama	30,800	18,300	400	800	0	32,000
19	Vina	34,400	28,700	300	600	0	35,300
20	Orland	79,500	42,700	600	500	0	80,600
21	Chico	90,600	40,100	400	2,200	700	93,900
22	Arbuckle	41,900	26,500	400	300	0	42,600
23	Colusa Trough	717,000	245,000	2,000	1,000	44,200	764,000
24	Feather River to Butte Slough	292,000	126,000	1,100	800	13,500	307,000
25	Yuba	100,000	54,000	400	1,300	700	102,000
26	Marysville-Sheridan	142,000	71,200	700	1,100	0	144,000
27	Woodland	161,000	70,000	700	2,400	0	164,000
28	Carmichael	104,000	57,600	800	28,800	2,000	136,000
29	Dixon	45,900	29,600	600	1,200	0	47,700
30	Yolo	150,000	63,700	600	200	100	151,000
	Subtotals, Valley Units	2,029,000	899,000	9,100	43,200	61,200	2,142,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	2,354,000	1,248,000	10,900	51,900	70,500	2,487,000
	Tulare Lake Basin						
	Mountain Units						
31	West Side, Kern County	0	0	0	0	0	0
32	Kern River and Tehachapi Mountains	23,800	7,200	100	200	400	24,500
33	Tule River	3,500	1,100	0	100	200	3,800
34	Kaweah River	300	100	0	0	100	400
35	Kings River	2,300	700	0	0	400	2,700
	Subtotals, Mountain Units	29,900	9,100	100	300	1,100	31,400
	Valley Units						
36	Antelope Plain	55,100	18,100	1,900	600	0	58,000
37	Kern	958,000	230,000	5,200	16,900	1,400	982,000
38	Earlimart	303,000	106,000	1,700	1,700	0	306,000
39	Visalia	523,000	214,000	2,700	7,400	0	533,000
40	Fresno-Hanford	1,455,000	510,000	7,300	27,300	700	1,490,000
41	Tulare Lake	256,000	93,500	1,900	400	0	258,000
	Subtotals, Valley Units	3,550,000	1,172,000	20,700	54,300	2,100	3,627,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	3,580,000	1,181,000	20,800	54,600	3,200	3,658,000

TABLE 115—Continued

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, CENTRAL VALLEY AREA

(In acre-feet)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands: Applied water	Irrigated lands: Precipitation	Farm lots: Applied water	Urban and suburban areas: Applied water	Unclassified areas: Applied water	Approximate total consumptive use of applied water
	San Joaquin River Basin						
	Mountain Units						
42	Mount Diablo	0	0	0	0	0	0
43	Altamont to San Luis Creek	0	0	0	0	0	0
44	West Side, Los Banos Creek to Avenal Creek	2,000	1,200	0	0	0	2,000
45	San Joaquin River	6,200	2,700	100	0	500	6,800
46	Chowchilla-Fresno Rivers	1,000	500	0	0	200	1,200
47	Merced River	1,400	900	0	100	2,200	3,700
48	Tuolumne River	2,300	2,100	0	400	700	3,400
49	Stanislaus River	2,100	1,000	0	200	700	3,000
50	Mokelumne-Calaveras Rivers	3,000	1,800	0	300	900	4,200
51	Cosumnes River	400	400	0	300	600	1,300
	Subtotals, Mountain Units	18,400	10,600	100	1,300	5,800	25,600
	Valley Units						
52	Antioch	103,000	47,200	600	2,600	0	106,000
53	Delta-Mendota	24,800	16,100	300	0	0	25,100
54	West Side, San Joaquin Valley	566,000	185,000	3,900	100	0	570,000
55	Madera	317,000	134,000	1,900	3,300	100	322,000
56	Merced	398,000	184,000	2,900	3,700	3,600	408,000
57	Los Banos	401,000	134,000	1,500	1,100	21,500	425,000
58	Modesto	394,000	236,000	3,100	5,000	0	402,000
59	Vernalis	114,000	50,500	600	200	0	115,000
60	Oakdale	289,000	157,000	1,300	1,600	0	292,000
61	Stockton	321,000	209,000	2,700	12,200	0	336,000
62	Ione	9,000	4,900	700	100	0	9,800
63	Sacramento-San Joaquin Delta	619,000	410,000	3,100	700	100	623,000
	Subtotals, Valley Units	3,556,000	1,768,000	22,600	30,600	25,300	3,634,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	3,574,000	1,779,000	22,700	31,900	31,100	3,660,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	9,508,000	4,208,000	54,400	138,000	105,000	9,805,000

Joaquin Delta are especially important to warm-water fishing. Irrigation canals and farm ponds also provide significant numbers of these fish.

The great Central Valley is the most important waterfowl area in California, and in addition plays an important role in the welfare of waterfowl on the entire Pacific Flyway. It is used mainly as a wintering area, and to a lesser degree for breeding. Approximately 3,500,000 ducks and geese are found in the valley each winter, and an average of 115,000 birds are produced there annually. The California Department of Fish and Game and the United States Fish and Wildlife Service maintain several waterfowl refuges and management areas in the area.

The Central Valley Area far exceeds the other parts of the State in opportunities for deer hunting. An estimated deer population of almost 500,000 provides about one-half of the annual deer take of California. Black bear are numerous in some localities, and the Central Valley Area also supports several herds of antelope. These latter are hunted only when census figures indicate that such hunting is desirable. Two small herds of elk, and a band of Sierra Nevadan bighorn sheep for which hunting is prohibited, are of particular interest to naturalists. Upland game birds consist of ring-necked pheasants, quail, and mourning doves. Sage hens and chukar partridges, when their hunting is permitted, and band-tailed pigeons also provide sport in local areas. Among the upland game mammals are cottontail, brush, and jack rabbits, and tree squirrels.

The quantities of water required to maintain or enhance these resources vary among the different groups. Anadromous fishes, particularly salmon and steelhead which spawn farther upstream than the others, require substantial flows of water in order that they can spawn successfully, and that the eggs can hatch. Such flows of water are necessary principally during the fall and winter months. At low dams or other barriers to migration, fishways are necessary in order that the migrant fishes can cross the barriers. Such fishways require a flow of water for their successful operation.

Resident fishes usually require smaller quantities of flowing water, but the requirement is year-round rather than seasonal. Flowing streams are needed throughout the year to insure satisfactory food production and spawning conditions for trout. In fluctuating reservoirs it is necessary to establish minimum pool elevations, so that fish populations will have sufficient water to support them at all times.

Water requirements for ducks and geese are substantial, and occur mainly during the fall and winter months. It is probable that much of the fresh water required to maintain waterfowl habitat in the future will be available from waste and return flows,

TABLE 116

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, CENTRAL VALLEY AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Other water service areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
	Sacramento River Basin						
	Mountain Units						
1	Goose Lake	39,700	26,300	100	300	0	40,100
2	Pit River	398,000	458,000	2,100	3,500	14,000	418,000
3	McCloud River	26,000	33,100	100	1,300	500	27,900
4	Sacramento River above Shasta Dam	13,000	13,000	100	1,800	600	15,500
5	West Side, Shasta Dam to Cottonwood Creek	54,200	50,900	200	500	800	55,700
6	East Side Cow Creek to Paynes Creek	144,000	125,000	500	1,800	1,200	147,000
7	Red Bluff to Thomas Creek	78,500	55,900	300	700	900	80,400
8	Antelope to Mud Creek	12,800	17,400	100	100	600	13,600
9	Stony Creek	75,300	52,500	300	700	1,000	77,300
10	Butte and Chico Creeks	17,800	29,800	100	1,300	200	19,400
11	Cortina Creek	66,900	51,200	300	700	200	68,100
12	Feather River	361,000	246,000	1,500	8,000	12,400	383,000
13	Yuba and Bear Rivers	216,000	162,000	900	7,200	15,100	239,000
14	Cache Creek	94,600	83,800	500	2,400	1,000	98,500
15	American River	134,000	114,000	700	7,700	4,600	147,000
16	Putah Creek	47,200	47,100	200	500	400	48,300
	Subtotals, Mountain Units	1,779,000	1,566,000	8,000	38,500	53,500	1,879,000
	Valley Units						
17	Anderson-Cottonwood	41,700	36,200	200	4,900	0	46,800
18	Tehama	147,000	112,000	700	3,100	0	151,000
19	Vina	108,000	96,400	600	2,500	0	111,000
20	Orland	227,000	148,000	800	2,000	0	230,000
21	Chico	164,000	97,600	1,200	7,600	700	174,000
22	Arbuckle	158,000	116,000	700	800	0	159,000
23	Colusa Trough	1,101,000	461,000	2,900	2,600	117,000	1,223,000
24	Feather River to Butte Slough	507,000	252,000	1,500	2,500	38,500	550,000
25	Yuba	127,000	76,800	600	3,100	1,400	132,000
26	Marysville-Sheridan	372,000	194,000	1,200	4,300	0	377,000
27	Woodland	341,000	180,000	1,100	4,600	0	347,000
28	Carmichael	343,000	223,000	1,400	72,000	2,000	418,000
29	Dixon	227,000	169,000	1,200	2,600	0	231,000
30	Yolo	391,000	176,000	1,000	600	100	393,000
	Subtotals, Valley Units	4,255,000	2,338,000	15,100	113,000	160,000	4,543,000
	APPROXIMATE TOTALS, SACRAMENTO RIVER BASIN	6,034,000	3,904,000	23,100	152,000	213,000	6,422,000
	Tulare Lake Basin						
	Mountain Units						
31	West Side, Kern County	20,000	6,000	100	100	300	20,500
32	Kern River and Tehachapi Mountains	350,000	118,000	1,200	2,300	1,800	355,000
33	Tule River	48,200	25,100	200	500	500	49,400
34	Kaweah River	26,400	15,800	100	300	500	27,300
35	Kings River	26,200	6,800	100	100	1,000	27,400
	Subtotals, Mountain Units	471,000	172,000	1,700	3,300	4,100	480,000
	Valley Units						
36	Antelope Plain	844,000	193,000	3,800	4,200	0	852,000
37	Kern	1,911,000	423,000	7,500	34,000	16,400	1,969,000
38	Earlimart	707,000	237,000	3,100	4,800	0	715,000
39	Visalia	732,000	322,000	3,300	14,800	0	750,000
40	Fresno-Hanford	1,763,000	647,000	8,600	53,500	700	1,826,000
41	Tulare Lake	484,000	108,000	1,900	2,200	0	488,000
	Subtotals, Valley Units	6,441,000	1,930,000	28,200	114,000	17,100	6,600,000
	APPROXIMATE TOTALS, TULARE LAKE BASIN	6,912,000	2,102,000	29,900	117,000	21,200	7,080,000

TABLE 116—Continued

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, CENTRAL VALLEY AREA

(In acre-feet)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands: Applied water	Irrigated lands: Precipitation	Farm lots: Applied water	Urban and suburban areas: Applied water	Other water service areas: Applied water	Approximate total consumptive use of applied water
	San Joaquin River Basin						
	Mountain Units						
42	Mount Diablo	15,900	12,000	100	100	100	16,200
43	Altamont to San Luis Creek	61,500	23,600	200	400	400	62,500
44	West Side, Los Banos Creek to Avenal Creek	82,700	35,600	300	700	800	84,500
45	San Joaquin River	12,300	5,400	0	100	1,300	13,700
46	Chowchilla-Fresno Rivers	46,200	18,600	100	300	500	47,100
47	Merced River	63,700	44,900	200	1,000	4,300	69,200
48	Tuolumne River	54,100	46,600	300	3,500	1,200	59,100
49	Stanislaus River	43,900	23,100	100	1,300	1,600	46,900
50	Mokelumne-Calaveras Rivers	98,800	71,100	600	2,200	1,600	103,000
51	Cosumnes River	71,400	68,800	400	2,300	1,000	75,100
	Subtotals, Mountain Units	550,000	350,000	2,300	11,900	12,800	577,000
	Valley Units						
52	Antioch	126,000	52,600	700	17,700	0	144,000
53	Delta-Mendota	123,000	50,900	500	700	0	124,000
54	West Side, San Joaquin Valley	1,517,000	341,000	5,700	7,100	0	1,530,000
55	Madera	758,000	302,000	3,100	4,900	5,000	771,000
56	Merced	813,000	379,000	3,100	7,300	15,000	838,000
57	Los Banos	581,000	186,000	2,000	3,800	34,000	621,000
58	Modesto	556,000	342,000	3,100	11,000	0	570,000
59	Vernalis	153,000	62,900	600	800	0	154,000
60	Oakdale	321,000	201,000	1,800	4,200	0	327,000
61	Stockton	789,000	490,000	3,500	29,000	0	822,000
62	Ione	201,000	121,000	1,000	1,100	0	203,000
63	Sacramento-San Joaquin Delta	668,000	424,000	3,200	3,500	100	675,000
	Subtotals, Valley Units	6,606,000	2,952,000	28,300	91,100	54,100	6,779,000
	APPROXIMATE TOTALS, SAN JOAQUIN RIVER BASIN	7,156,000	3,302,000	30,600	103,000	66,900	7,356,000
	APPROXIMATE TOTALS, CENTRAL VALLEY AREA	20,100,000	9,308,000	83,600	372,000	301,000	20,860,000

although additional supplies may be needed. The importance of providing water for these natural resources was recently recognized with the passage by Congress of the Grasslands Water Bill, which will provide water from the Central Valley Project, when available, for flooding about 100,000 acres on the west side of the San Joaquin Valley. The flooded area will be operated as a fall and winter waterfowl concentration area.

Although the other game species are quite numerous, their water requirements are minor in amount. The necessary water supplies are expected to be available from natural sources or small local developments.

At the request of the Division of Water Resources, a series of estimates was made by the California Department of Fish and Game of the stream flow at certain points in the more important streams of the Central Valley Area which would be required for the protection and maintenance of fish life. The streams were divided into four classes, according to the anticipated degree of water development for various beneficial purposes that might compete with the requirements for fish. The summer and winter stream flow requirements for fish life in Central Valley Area streams, as estimated by the Department of Fish and Game, are listed in Appendix F.

Flood Control. The protection of lowland areas from floods has been a major consideration in the management of water resources in the Central Valley Area. Beginning with the influx of settlers during the period following the discovery of gold, the agricultural potential of the vast areas of swamp and overflow lands was realized, and the construction of low levees to protect individual tracts of land commenced. Competitive development led to extreme difficulties in the control of flood waters, and eventually resulted in governmental supervision and participation in flood control works.

Federal participation in flood control works in California first developed in connection with national responsibilities for the improvement of rivers and harbors for navigation. The California Debris Commission Act, passed by Congress in 1893, provided that the Commission "mature and adopt plans for the purpose of improving the navigability, deepening

TABLE 117

DISTRIBUTION OF MONTHLY WATER DEMANDS, CENTRAL VALLEY AREA

(In per cent of seasonal total)

Locality and purpose	January	February	March	April	May	June	July	August	September	October	November	December	Total
Irrigation demand													
Sacramento River Diversions, 1941 through 1951	0	0	0.5	7.4	17.6	18.7	20.9	19.7	11.3	3.9	0	0	100.0
Feather River Diversions, 1941 through 1951	0	0	0.1	5.0	18.0	19.4	20.7	18.9	12.1	5.8	0	0	100.0
Yuba River Diversions, 1941 through 1951	0	0	0.2	5.4	14.9	16.9	17.8	17.4	15.0	12.4	0	0	100.0
San Joaquin River Diversions (Fremont Ford-Vernalis), 1941 through 1951	0	0	3.7	12.4	15.3	15.3	21.3	18.3	10.9	2.8	0	0	100.0
Merced River Diversions, 1941 through 1951	0	0	1.4	7.1	13.9	18.8	23.3	19.1	12.6	3.8	0	0	100.0
Tuolumne River Diversions, 1941 through 1951	0	0	2.7	8.7	14.6	17.4	19.1	19.2	13.3	5.0	0	0	100.0
Stanislaus River Diversions, 1941 through 1951	0	0	2.2	9.2	14.9	17.5	19.4	18.5	12.8	5.5	0	0	100.0
Visalia to Delano Area, agricultural pumping load, 1947 through 1951	2.0	1.6	3.0	6.5	8.6	9.6	13.3	16.5	16.4	12.0	6.0	4.5	100.0
Madera-Merced Area, 1947 through 1951	0.8	1.2	2.5	5.3	8.8	12.3	18.0	20.1	17.5	8.6	3.4	1.5	100.0
Fresno Area, 1947 through 1951	0.9	1.3	3.1	6.8	7.6	9.8	17.2	23.0	17.1	7.5	3.8	1.9	100.0
Coalinga-Los Banos Area, 1947 through 1951	5.9	7.8	9.9	8.1	6.3	5.2	9.0	10.4	10.8	9.4	9.2	8.0	100.0
Corcoran-Kern Area, 1947 through 1951	2.3	2.8	5.8	9.6	7.8	8.4	13.6	17.5	16.8	8.3	4.3	2.8	100.0
Sacramento-Stockton Area, 1947 through 1951	1.9	1.9	2.6	4.3	10.1	14.2	17.9	19.3	15.5	7.2	3.1	2.0	100.0
Urban demand													
Sacramento, 1946	5.5	5.0	6.1	7.8	9.2	11.8	12.8	12.2	10.1	7.7	6.1	5.7	100.0
Stockton, 1946	4.9	5.1	5.1	6.4	9.5	10.1	11.7	13.0	12.3	9.2	7.3	5.4	100.0
Sonora, 1946	6.7	6.0	6.7	6.7	9.5	8.7	9.2	10.7	7.6	9.6	9.8	8.8	100.0
Fresno, 1947	4.2	4.4	4.5	5.8	10.3	10.9	12.6	13.7	12.3	8.9	6.7	5.7	100.0
Bakersfield, 1947	4.7	5.1	6.6	8.1	9.9	10.6	12.2	12.1	10.8	8.7	5.9	5.3	100.0

the channels, and protecting the banks of the rivers, and affording relief from flood damages." Under this act, which had as its primary purpose the regulation of hydraulic mining and the deposition of debris in outflow areas of the tributary streams, reports on plans and projects for navigation, debris control, and flood control were presented to and adopted by Congress. The first comprehensive plan for flood control along the Sacramento River was recommended by the Chief of Engineers in 1911, and adopted by Congress as a part of the Flood Control Act of 1917. In 1911 the State of California recognized the interest of the State in the erection, maintenance, and protection of reclamation works on the Sacramento and San Joaquin river systems. The State Reclamation Board, created by the 1911 statute, was authorized to pass upon and approve plans for such reclamation. Since 1917, the State and Federal Governments have had a joint interest in flood control in the Central Valley Area.

The flood control acts approved by Congress have provided for local participation in the construction of authorized projects. The 1917 Flood Control Act provided generally that local interests should pay at least one-half of construction costs, furnish rights of way, and maintain the completed project. The 1936 act freed local interests of responsibility for construction costs, but they were required to provide lands, easements, and rights of way, hold the United States free from damages, and maintain and operate completed projects. In 1938 the principle of local contribution of rights of way was abandoned by Congress for projects authorized under the 1936 and subsequent acts. In 1941, however, the federal acquisition of rights of way was limited to those flood control features involving dams and reservoirs, and local interests were required to provide rights of way for channel rectification or improvement.

The Sacramento River Flood Control Project is a joint federal-state-local development. The Corps of Engineers, United States Army, presently constructs project works and maintains navigable river channels. The State operates and maintains specified portions of the completed works, other than navigable channels. The remaining works are maintained by reclamation, drainage, or levee districts, or by municipalities. The Legislature, by Chapter 1528, Statutes of 1947, assured adequate and proper maintenance of works assigned such local agencies. This act established the procedure for annual inspection and report of conditions of such works, and provided that the State should accomplish the necessary maintenance in case of failure of local agencies to do so, with costs assessed against benefited areas. Construction costs of the

TABLE 118

ESTIMATED WEIGHTED MEAN IRRIGATION WATER SERVICE AREA EFFICIENCY WITHIN HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

(In per cent)

Hydrographic unit: Reference number	Hydrographic unit: Name	Present	Probable ultimate	Hydrographic unit: Reference number	Hydrographic unit: Name	Present	Probable ultimate
	Sacramento River Basin				**Tulare Lake Basin**		
					Mountain Units		
	Mountain Units			31	West Side, Kern County	0	50
				32	Kern River and Tehachapi Mountains	50	50
1	Goose Lake	45	50	33	Tule River	50	50
2	Pit River	45	70	34	Kaweah River	50	50
3	McCloud River	45	50	35	Kings River	50	50
4	Sacramento River above Shasta Dam	45	50				
5	West Side, Shasta Dam to Cottonwood Creek	50	50		Valley Units		
				36	Antelope Plain	85	90
6	East Side, Cow Creek to Paynes Creek	50	50	37	Kern	85	80
				38	Earlimart	90	85
7	Red Bluff to Thomes Creek	0	50	39	Visalia	90	85
8	Antelope to Mud Creek	50	50	40	Fresno-Hanford	90	80
9	Stony Creek	50	60	41	Tulare Lake	70	80
10	Butte and Chico Creeks	60	60				
11	Cortina Creek	0	50		**San Joaquin River Basin**		
12	Feather River	50	75		Mountain Units		
13	Yuba and Bear Rivers	50	50	42	Mount Diablo	0	50
14	Cache Creek	50	60	43	Altamont to San Luis Creek	0	50
15	American River	60	60	44	West Side, Los Banos Creek to Avenal Creek	50	50
16	Putah Creek	50	50				
				45	San Joaquin River	50	50
				46	Chowchilla-Fresno Rivers	50	50
	Valley Units			47	Merced River	50	50
				48	Tuolumne River	50	50
17	Anderson-Cottonwood	25	50	49	Stanislaus River	50	50
18	Tehama	60	75	50	Mokelumne-Calaveras Rivers	50	50
19	Vina	60	80	51	Cosumnes River	50	50
20	Orland	60	75				
21	Chico	60	80		Valley Units		
22	Arbuckle	60	70	52	Antioch	70	70
23	Colusa Trough	50	70	53	Delta-Mendota	50	90
24	Feather River to Butte Slough	40	75	54	West Side, San Joaquin Valley	95	90
25	Yuba	90	80	55	Madera	80	85
26	Marysville-Sheridan	70	90	56	Merced	45	80
27	Woodland	65	85	57	Los Banos	45	80
28	Carmichael	65	60	58	Modesto	45	85
29	Dixon	65	75	59	Vernalis	60	65
30	Yolo	65	70	60	Oakdale	50	90
				61	Stockton	40	85
				62	Ione	40	60
				63	Sacramento-San Joaquin Delta	75	90

Sacramento River Flood Control Project as of 1955 were about $51,000,000 to the United States, and about $85,000,000 to the State of California and to local interests, making a total cost of approximately $136,000,000.

In 1945 the State of California, recognizing the general state interest in the control of floods, established the State Water Resources Board to formulate state policy and provide the necesary cooperation on federal projects authorized by Congress and adopted by the State Legislature. The State Water Resources Act provided that appropriations would be made by the State to pay for all lands, easements, and rights of way required of local agencies in connection with federally authorized flood control projects. The statute also charged local agencies with the responsibility for the operation and maintenance of completed flood control and other works in all cases where the Federal Government requires such local participation.

The Sacramento River Flood Control Project, as presently approved, comprises about 450 miles of stream channels and canals, 95 miles of by-passes, and 1,000 miles of levees for the passage of flood flows, and numerous major control works. A comprehensive plan has been adopted for flood control on the San Joaquin River, and several major projects which comprise portions of this plan have already been authorized. Among these are the Littlejohns Creek and Calaveras River Stream Groups Project in San Joaquin County, the Merced County Stream Group Project, the Fresno County Stream Group Project, and the project on the Lower San Joaquin River and tributaries. The plan authorized by Congress includes the reservation of a considerable acreage of lowland area for excess flows along the San Joaquin River upstream from the mouth of Merced River. Recent development in this region, however, has greatly increased land values and costs of acquisition, and modification of the plan is in progress.

A flood control reservation of 1,300,000 acre-feet is incorporated in the operating criteria for Shasta Reservoir on the Sacramento River, and a reservation of 400,000 acre-feet is allocated for flood storage in Folsom Reservoir on the American River. In the San Joaquin Valley, eight reservoirs have been built for flood control purposes by the Corps of Engineers, on projects authorized pursuant to the Flood Control Acts of 1936 and 1944, and the companion state legislation of 1945. Two of these, Pine Flat Reservoir on the Kings River and Isabella Reservoir on the Kern River, have just been completed. About 500,000 acre-feet of flood control reservation is being provided in Friant and Don Pedro Reservoirs. Hogan Reservoir, on the Calaveras River, has been built by the City of Stockton for the protection of that city from floods. The levee system is not completely coordinated in the San Joaquin River and Tulare Lake Basins, although a general plan for protection has been authorized to which future construction must substantially conform.

As of 1950, the Sacramento River Flood Control Project was estimated to provide protection at Sacramento against a flood expected to occur not more frequently than once in 25 years, but the completion of Folsom Reservoir should protect against floods expected to occur at intervals of several hundred years. In other parts of the project, the degree of protection afforded varies from once in 15 years to once in 170 years. Future adequate protection would be provided by construction of additional flood control reservoirs, notably Black Butte on Stony Creek, Table Mountain on the Sacramento River, and Oroville Reservoir on the Feather River. An alternative to the construction of a dam at Table Mountain is a proposal for the reclamation of Butte Basin by a system of levees and a by-pass channel. Present plans for Oroville Reservoir on the Feather River include a 500,000 acre-foot flood control reservation that will provide a high degree of protection to lands and communities along that stream.

The future construction of Success and Terminus Reservoirs on the Tule and Kaweah Rivers, together with the completion of Pine Flat and Isabella Reservoirs, will provide a substantial degree of flood protection in the Tulare Lake Basin. To attain substantial improvements in the protection from floods in the San Joaquin River Basin, additional construction providing new or increased flood control reservations is needed at Hogan Reservoir on the Calaveras River, Melones on the Stanislaus, Don Pedro on the Tuolumne, and on Bear Creek in Merced County.

Releases of water from multipurpose reservoirs for the control of floods may be substantial in amount. Flood control releases must be given consideration in future plans to meet the water requirements of the areas concerned. The plans must provide for methods of operation of such reservoirs to meet the requirements of all functions without serious impairment of any.

Navigation. Water-borne commerce in the Central Valley Area is restricted largely to the Sacramento River and the delta channels, including the Stockton Deep Water Channel. Substantial investments have been made in ship channels, floating equipment, docks, and storage terminals, and further developments are presently contemplated.

Navigable channels may be provided by the installation of low dams across stream channels, with lockage facilities in order to provide passage of vessels. Navigable depths may also be provided by the maintenance of stream flow in sufficient quantity. Both methods involve the use of appreciable quantities of water, which may or may not be provided from return flows resulting from other uses of water. Determination of the water supplies necessary for navigation can be made only after definite project proposals have been formulated. No estimates of future water requirements in the Central Valley Area for navigation were made for the purposes of this bulletin.

Salinity Control. Intrusion of saline water from San Francisco Bay has long been a problem in the channels of the Sacramento-San Joaquin Delta. During periods of low stream flow and with increased use of fresh water for upstream consumptive uses, the natural fresh-water outflow is not sufficient to repel saline waters. The tides further increase the problem by forcefully propelling saline waters into the bypasses and channels of the Delta. The tidal effects act to impede fresh-water outflow by raising water surface elevations, and by forming a barrier to flow during periods of high tide.

The historical method of maintaining the quality of the waters of the Delta for irrigation use involves a continuous flow of fresh water through the channels of the area and into Suisun Bay. It has been variously estimated that to limit the salinity near Antioch to an average content of not more than 100 parts of chloride per 100,000 parts of water, with decreasing salinity upstream, a flow of from 3,300 to 4,500 second-feet is necessary. Recent measurements are currently being evaluated in an attempt to more precisely define this figure. Proposals have been advanced for a barrier in or below the Delta as a means of conserving a portion of this water requirement. The Division of Water Resources has recently conducted an investigation to determine the water requirements and feasibility of these proposals.

Hydroelectric Power. The Central Valley Area has by far the greatest amount of developed hydroelectric power in California. The combination of substantial stream runoff and favorable elevations in the Sacramento River Basin has made possible a more intensive development than in the southern portions of the Central Valley Area. In the San Joaquin and Tulare Lake Basins, however, the greater ranges in elevation, and the resulting greater possible heads, have compensated in a large part for the lesser water supplies in the development of hydroelectric power facilities. These factors will probably continue to exert a similar influence in the future.

It is probable that the available water supply of the Central Valley Area will ultimately serve a combination of many beneficial uses, certain of which will conflict with use of the water for generation of energy. However, estimates were made of the potential hydroelectric power development under the assumption that stream runoff would be used primarily for power production, and with no consideration given to use of the water for other purposes. Table 119 presents data on the present hydroelectric power installations in the Central Valley Area, and on the average seasonal water requirement of the plant with the greatest water demand on a stream system. Table 120 presents estimates of the potential annual power output, installed power capacity, and water demand at the lowest plant on a stream system, under an assumed ultimate development of the water primarily for this purpose.

TABLE 119

PRESENT HYDROELECTRIC POWER DEVELOPMENT, CENTRAL VALLEY AREA

Stream	Number of power plants	Installed power capacity, in 1,000 kilowatts	Present annual water requirement, in acre-feet
Sacramento River Basin			
Pit River	6	383	1,644,000
Sacramento River	2	450	5,915,000
Cow Creek	2	5	52,000
Battle Creek	4	31	196,000
Feather River	10	410	1,766,000
North Fork Yuba River	3	44	454,000
Yuba and Bear Rivers	9	124	381,000
American River	4	202	2,230,000
TOTALS, SACRAMENTO RIVER BASIN	40	1,649	
San Joaquin River Basin			
Mokelumne River	6	222	442,000
Stanislaus River	6	78	618,000
Tuolumne River	4	176	1,340,000
Merced River	3	37	805,000
Willow Creek	5	29	249,000
San Joaquin River	7	487	1,305,000
TOTALS, SAN JOAQUIN RIVER BASIN	31	1,029	
Tulare Lake Basin			
Kings River	1	34	103,000
Kaweah River	3	7	64,000
Tule River	2	8	25,000
Kern River	4	66	327,000
TOTALS, TULARE LAKE BASIN	10	115	
TOTALS, CENTRAL VALLEY AREA	81	2,793	

TABLE 120

EXISTING AND ESTIMATED POTENTIAL HYDROELECTRIC POWER DEVELOPMENT, CENTRAL VALLEY AREA

Stream	Average annual power output, in 1,000,000 kilowatt-hours	Installed power capacity, in 1,000 kilowatts	Average annual water requirement at lowest plant, in 1,000 acre-feet
Sacramento River Basin			
Sacramento River above Keswick	5,670	1,180	3,450
Minor East Side Tributaries	780	160	770
Minor West Side Tributaries	260	55	1,110
Feather River	6,470	1,345	2,640
Yuba River	3,000	625	1,430
Bear River	100	20	200
American River	3,000	625	1,600
TOTALS, SACRAMENTO RIVER BASIN	19,280	4,010	
San Joaquin River Basin			
Cosumnes River	65	15	215
Mokelumne River	1,060	220	450
Calaveras River	25	5	95
Stanislaus River	1,850	385	710
Tuolumne River	3,240	675	1,150
Merced River below Yosemite Park	540	110	615
San Joaquin River	4,510	940	1,080
TOTALS, SAN JOAQUIN RIVER BASIN	11,290	2,350	
Tulare Lake Basin			
Kings River	2,860	595	1,020
Kaweah River	90	20	260
Tule River	50	10	85
Kern River	1,210	250	440
TOTALS, TULARE LAKE BASIN	4,210	875	
TOTALS, CENTRAL VALLEY AREA	34,780	7,235	

Requirements of a Consumptive Nature

Estimates of present and probable ultimate water requirements of a consumptive nature within hydrographic units of the Central Valley Area are presented in Table 121. These mean seasonal values represent the amount of water other than precipitation needed to provide for beneficial consumptive use of water on irrigated lands, urban and suburban areas, farm lots, and other water service areas, and for irrecoverable losses of water incidental to these uses. The estimates were derived from consideration of the heretofore presented estimates of consumptive use of applied water, and of water service area efficiencies of hydrographic units.

Table 122 presents estimates of the total water requirements for each of the three major basins of the Central Valley Area. This analysis gives consideration to the re-use of water in those hydrographic units which are geographically situated so as to enable the rediversion of return flow from upstream units.

TABLE 121

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER IN HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots		Urban and suburban areas		Other water service areas		Approximate totals	
Reference number	Name	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate
	Sacramento River Basin										
	Mountain Units										
1	Goose Lake	24,000	79,400	100	300	0	500	0	0	24,100	80,200
2	Pit River	241,000	569,000	1,300	4,200	1,100	7,000	1,000	14,000	244,000	594,000
3	McCloud River	6,200	52,000	0	300	600	2,500	100	500	6,900	55,300
4	Sacramento River above Shasta Dam	5,300	26,000	0	100	800	3,600	200	600	6,300	30,300
5	West Side, Shasta Dam to Cottonwood Creek	4,800	108,000	0	500	200	1,000	100	800	5,100	110,000
6	East Side, Cow Creek to Paynes Creek	16,400	288,000	0	1,100	600	3,600	600	1,200	17,600	294,000
7	Red Bluff to Thomes Creek	0	157,000	0	500	0	1,300	300	900	300	160,000
8	Antelope to Mud Creek	3,200	25,600	0	100	0	200	200	600	3,400	26,500
9	Stony Creek	2,200	126,000	0	600	0	1,300	300	1,000	2,500	129,000
10	Butte and Chico Creeks	3,300	29,700	0	200	500	2,600	100	200	3,900	32,700
11	Cortina Creek	0	134,000	0	500	0	1,300	0	200	0	136,000
12	Feather River	177,000	481,000	1,200	3,000	7,700	16,000	3,500	12,400	189,000	512,000
13	Yuba and Bear Rivers	84,600	432,000	300	1,800	2,500	14,400	1,900	15,100	89,300	463,000
14	Cache Creek	27,800	158,000	200	1,000	600	4,800	200	1,000	28,800	165,000
15	American River	58,700	223,000	600	1,400	2,700	15,400	800	4,600	62,800	244,000
16	Putah Creek	9,400	94,400	0	400	200	1,000	0	400	9,600	96,200
	Valley Units										
17	Anderson-Cottonwood	160,000	83,400	300	400	4,000	9,800	0	0	164,000	93,600
18	Tehama	51,300	196,000	700	1,300	1,600	6,200	0	0	53,600	204,000
19	Vina	57,300	135,000	500	1,200	1,200	5,000	0	0	59,000	141,000
20	Orland	132,000	303,000	1,300	1,700	1,000	3,900	0	0	134,000	309,000
21	Chico	151,000	204,000	800	2,300	4,500	15,100	700	700	157,000	222,000
22	Arbuckle	69,800	225,000	900	1,400	600	1,500	0	0	71,300	228,000
23	Colusa Trough	1,434,000	1,574,000	4,000	5,800	2,000	5,200	44,200	116,000	1,484,000	1,701,000
24	Feather River to Butte Slough	729,000	676,000	2,200	3,000	1,600	5,000	13,500	38,500	746,000	722,000
25	Yuba	111,000	159,000	800	1,200	2,500	6,200	700	1,400	115,000	168,000
26	Marysville-Sheridan	203,000	413,000	1,400	2,400	2,200	8,600	0	0	207,000	424,000
27	Woodland	248,000	401,000	1,500	2,100	4,800	9,100	0	0	254,000	412,000
28	Carmichael	159,000	571,000	1,600	2,800	57,600	144,000	2,000	2,000	220,000	720,000
29	Dixon	70,600	303,000	1,200	2,400	2,400	5,300	0	0	74,200	311,000
30	Yolo	232,000	559,000	1,200	2,000	400	1,200	100	100	234,000	562,000
	Tulare Lake Basin										
	Mountain Units										
31	West Side, Kern County	0	40,000	0	200	0	300	0	300	0	40,800
32	Kern River and Tehachapi Mountains	47,600	700,000	200	2,400	400	4,700	400	1,800	48,600	709,000
33	Tule River	7,000	96,400	0	400	200	1,000	200	500	7,400	98,300
34	Kaweah River	600	52,800	0	200	0	500	100	500	700	54,000
35	Kings River	4,600	52,400	0	100	0	300	400	1,000	5,000	53,800
	Valley Units										
36	Antelope Plain	64,800	937,000	3,700	7,600	1,200	8,400	0	0	69,700	953,000
37	Kern	1,127,000	2,389,000	10,400	15,000	33,800	68,000	1,400	16,400	1,173,000	2,488,000
38	Earlimart	337,000	832,000	3,400	6,300	3,400	9,500	0	0	344,000	848,000
39	Visalia	582,000	861,000	5,400	6,700	14,800	30,000	0	0	602,000	898,000
40	Fresno-Hanford	1,617,000	2,204,000	14,700	17,200	54,600	107,000	700	700	1,687,000	2,329,000
41	Tulare Lake	365,000	606,000	3,800	3,900	800	4,500	0	0	370,000	614,000
	San Joaquin River Basin										
	Mountain Units										
42	Mount Diablo	0	31,800	0	200	0	300	0	100	0	32,400
43	Altamont to San Luis Creek	0	123,000	0	400	0	800	0	400	0	125,000
44	West Side, Los Banos Creek to Avenal Creek	4,000	165,000	0	700	0	1,300	0	800	4,000	168,000
45	San Joaquin River	12,400	24,600	0	0	0	200	500	1,300	12,900	26,100
46	Chowchilla-Fresno Rivers	2,000	92,400	0	300	0	500	200	500	2,200	93,700
47	Merced River	2,800	127,000	0	400	200	2,100	2,200	4,300	5,200	134,000
48	Tuolumne River	4,600	108,000	0	500	800	7,000	700	1,200	6,100	117,000
49	Stanislaus River	4,200	87,800	0	300	400	2,600	700	1,600	5,300	92,300
50	Mokelumne-Calaveras Rivers	6,000	198,000	0	1,100	600	4,400	900	1,600	7,500	205,000
51	Cosumnes River	800	143,000	0	800	600	4,600	600	1,000	2,000	149,000
	Valley Units										
52	Antioch	147,000	180,000	1,200	1,300	5,200	35,400	0	0	153,000	217,000
53	Delta-Mendota	49,600	137,000	600	1,000	0	1,400	0	0	50,200	139,000
54	West Side, San Joaquin Valley	596,000	1,686,000	7,800	11,400	200	14,300	0	0	604,000	1,712,000
55	Madera	396,000	892,000	3,900	6,200	6,600	9,900	100	5,000	407,000	913,000
56	Merced	885,000	1,016,000	5,800	6,100	7,400	14,600	3,600	15,000	902,000	1,052,000
57	Los Banos	891,000	726,000	3,000	4,100	2,200	7,600	21,500	34,100	918,000	772,000
58	Modesto	876,000	654,000	6,300	6,300	10,000	22,100	0	0	892,000	682,000
59	Vernalis	190,000	235,000	1,100	1,200	500	1,700	0	0	192,000	238,000
60	Oakdale	578,000	356,000	2,500	3,600	3,200	8,300	0	0	584,000	368,000
61	Stockton	803,000	929,000	5,400	6,900	24,400	57,800	0	0	833,000	994,000
62	Ione	22,000	336,000	1,300	2,000	200	2,200	0	0	23,500	340,000
63	Sacramento-San Joaquin Delta	826,000	742,000	6,100	6,400	1,400	7,000	100	100	834,000	756,000

TABLE 122

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER IN MAJOR BASINS, CENTRAL VALLEY AREA

(In acre-feet)

Basin	Present	Probable ultimate
Sacramento River	3,819,000	7,720,000
Tulare Lake	4,280,000	8,657,000
San Joaquin River (including Delta)	5,093,000	7,648,000
APPROXIMATE TOTALS, CENTRAL VALLEY AREA	13,190,000	24,030,000

It may be noted that because of this re-use of water the requirements shown in this table do not represent the sum of the requirements of the individual hydrographic units contained in the respective basins. Rather, the table indicates the depletion in the total water supply of the respective basins caused by development and use of the water.

Supplemental Requirements

In general, the present supplemental water requirement in each hydrographic unit of the Central Valley Area was taken as equivalent to the estimated ground water overdraft, when such was known to exist. The difference between estimated present and probable ultimate water requirements for each hydrographic unit plus the present supplemental requirement was taken as the measure of the probable ultimate supplemental water requirement, except for adjustments made necessary by reason of supplies of supplemental water expected to be delivered through the Friant-Kern and Madera Canals.

Results of prior studies of the use of ground water in the Central Valley Area indicated that overdrafts exist in ground water basins of the Tehama, Arbuckle, Yuba, Marysville-Sheridan, Carmichael, Antelope Plain, Kern, Earlimart, Visalia, Fresno-Hanford, Tulare Lake, Delta-Mendota, West Side San Joaquin Valley, Madera, Stockton, and Ione Hydrographic Units. In many of the ground water basins where progressive lowering of the water table now occurs, the indicated present overdraft is less than the estimated present supplemental water requirement shown in Table 124. This results from the excessive lowering of ground water levels which has occurred in the basins concerned, and which has induced a greater than normal subsurface inflow of water from adjacent areas. The future import of supplemental water to the areas will result in gradual accretion to the ground water underlying the lands served. In the course of time, the existing hydraulic gradients will tend to approach stabilization at lessened slopes, or the slopes may even become reversed in direction. It is evident that in such cases the present subsurface inflow cannot be considered a permanent water supply. The estimates of present supplemental water requirement for this bulletin, therefore, were adjusted accordingly.

In the areas in which as the result of prior investigations an overdraft is known to exist, the use of ground water generally has intensified since the date of the studies. On the other hand, since the time that some of the earlier investigations were made, the Friant-Kern Canal has been supplying water to a portion of the San Joaquin Valley, in the varying amounts shown in Table 123. In many instances the distribution systems are still in the process of construction in the irrigation districts concerned. Where the facilities permit, a portion of the Friant-Kern water has been applied to lands for the specific purpose of recharging ground water basins. Specific data regarding the amount of such water usage are not available, and for the purpose of estimating present supplemental requirements it was assumed that these works were not in operation.

TABLE 123

SEASONAL WATER DELIVERIES IN SAN JOAQUIN RIVER AND TULARE LAKE BASINS THROUGH FRIANT-KERN CANAL

(In acre-feet)

Month	Season					
	1948-49	1949-50	1950-51	1951-52	1952-53	1953-54
October	0	0	0	14,400	73,000	22,500
November	0	0	0	8,800	17,500	7,400
December	0	0	0	0	0	0
January	0	0	0	0	200	0
February	0	0	0	4,700	1,100	11,900
March	1,300	15,200	23,500	2,800	56,400	52,800
April	1,300	22,400	37,400	12,100	54,200	58,000
May	0	17,800	11,800	28,900	40,100	124,000
June	500	52,900	65,900	55,700	99,300	153,000
July	16,400	45,600	108,000	126,000	164,000	172,000
August	22,700	41,500	86,100	138,000	160,000	146,000
September	3,000	100	35,800	69,900	74,600	63,000
TOTALS	45,200	195,000	368,000	461,000	740,000	811,000

Present supplemental water requirements for valley hydrographic units in the Tulare Lake Basin were estimated by inflow-outflow studies, using available water supply and utilization data. The use of water in remaining hydrographic units, where no deficiencies are known to exist, is primarily by stream diversion, or by ground water pumpage without apparent overdraft.

In the determination of ultimate supplemental water requirements, the water supplied through the Friant-Kern Canal from Friant Reservoir was allocated to hydrographic units on the basis of modification of the existing contracts, with the total delivery of water equal to the estimated safe yield of Friant Reservoir. This allocation is set forth in the following tabulation:

Hydrographic unit — *Reference number*	*Name*	*Estimated ultimate supplemental seasonal water supply from Friant Reservoir, in acre-feet*
37	Kern	459,000
38	Earlimart	512,000
39	Visalia	227,000
40	Fresno-Hanford	6,100
55	Madera	418,000
	TOTAL	1,622,000

It should be pointed out that estimated ultimate surface water supplies available to the Antioch, Modesto, Stockton, and Ione Hydrographic Units are less than the total probable developed water supplies in the tributary watersheds by the amount of exportations to the San Francisco Bay Area. These exportations of water are made through the Contra Costa Canal, the Mokelumne Aqueduct of the East Bay Municipal Utility District, and the Hetch Hetchy Aqueduct of the San Francisco Public Utilities Commission. These systems, under conditions of presently planned development, will export 195,000 acre-feet, 224,000 acre-feet, and 448,000 acre-feet of water per year, respectively, from the Central Valley Area.

In determining ultimate supplemental water requirements, consideration was given to the recovery of return flow from an upstream or mountain hydrographic unit by a downstream or valley unit. Supplemental water available for re-use by a downstream unit was evaluated by applying appropriate factors to the amount of applied water required by the up-

TABLE 124

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS IN HYDROGRAPHIC UNITS, CENTRAL VALLEY AREA

(In acre-feet)

Hydrographic unit — Reference number	Name	Present	Probable ultimate
	Sacramento River Basin		
	Mountain Units		
1	Goose Lake	0	56,100
2	Pit River	0	350,000
3	McCloud River	0	48,400
4	Sacramento River above Shasta Dam	0	24,000
5	West Side, Shasta Dam to Cottonwood Creek	0	105,000
6	East Side, Cow Creek to Paynes Creek	0	276,000
7	Red Bluff to Thomes Creek	0	160,000
8	Antelope to Mud Creek	0	23,100
9	Stony Creek	0	127,000
10	Butte and Chico Creeks	0	28,800
11	Cortina Creek	0	136,000
12	Feather River	0	323,000
13	Yuba and Bear Rivers	0	374,000
14	Cache Creek	0	136,000
15	American River	0	181,000
16	Putah Creek	0	86,600
	Valley Units		
17	Anderson-Cottonwood		
18	Tehama	0	0
19	Vina	3,000	153,000
20	Orland	0	82,000
21	Chico	0	175,000
22	Arbuckle	0	65,000
23	Colusa Trough	9,300	166,000
24	Feather River to Butte Slough	0	217,000
25	Yuba	0	0
26	Marysville-Sheridan	15,000	68,000
27	Woodland	70,000	287,000
28	Carmichael	0	158,000
29	Dixon	27,000	527,000
30	Yolo	0	237,000
		0	328,000

Hydrographic unit — Reference number	Name	Present	Probable ultimate
	Tulare Lake Basin		
	Mountain Units		
31	West Side, Kern County	0	40,800
32	Kern River and Tehachapi Mountains	0	660,000
33	Tule River	0	90,900
34	Kaweah River	0	53,300
35	Kings River	0	48,800
	Valley Units		
36	Antelope Plain	11,800	895,000
37	Kern	215,000	1,530,000
38	Earlimart	211,000	715,000
39	Visalia	158,000	454,000
40	Fresno-Hanford	91,100	733,000
41	Tulare Lake	184,000	428,000
	San Joaquin River Basin		
	Mountain Units		
42	Mount Diablo	0	32,400
43	Altamont to San Luis Creek	0	125,000
44	West Side, Los Banos Creek to Avenal Creek	0	164,000
45	San Joaquin River	0	13,200
46	Chowchilla-Fresno Rivers	0	91,500
47	Merced River	0	129,000
48	Tuolumne River	0	111,000
49	Stanislaus River	0	87,000
50	Mokelumne-Calaveras Rivers	0	198,000
51	Cosumnes River	0	147,000
	Valley Units		
52	Antioch	0	64,000
53	Delta-Mendota	20,200	109,000
54	West Side, San Joaquin Valley	524,000	1,632,000
55	Madera	133,000	639,000
56	Merced	0	150,000
57	Los Banos	0	0
58	Modesto	0	0
59	Vernalis	0	46,000
60	Oakdale	0	0
61	Stockton	103,000	264,000
62	Ione	10,000	326,000
63	Sacramento-San Joaquin Delta	0	0

stream unit but not beneficially used in that unit. The summation of the supplemental water requirements in all hydrographic units deriving their water supply from the same stream basin, less the supplemental return flow available for re-use within the basin, was taken to be the supplemental water requirement for the stream basin as a whole.

Table 124 presents estimates of present and probable ultimate mean seasonal supplemental water requirements of hydrographic units of the Central Valley Area. Table 125 gives estimated basin supplemental requirements after consideration of re-use of return flow.

TABLE 125

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS IN MAJOR BASINS, CENTRAL VALLEY AREA

(In acre-feet)

Basin	Present	Probable ultimate
Sacramento River Basin	124,000	4,157,000
Tulare Lake Basin	871,000	4,044,000
San Joaquin River Basin	790,000	3,539,000
APPROXIMATE TOTALS, CENTRAL VALLEY AREA	1,785,000	11,740,000

Donner Summit

Courtesy State Division of Highways

Lake Tahoe

Courtesy State Division of Highways

CHAPTER VIII

LAHONTAN AREA

The Lahontan Area lies along the California-Nevada border between latitudes 35° 30′ and 42° N., and consists of those lands generally easterly from the drainage divide of the Sierra Nevada, and the Tehachapi, San Gabriel, and San Bernardino Mountains, including the drainage basins of Death Valley and the Mojave River. The area is designated Area 6 on Plate 8, and includes the Counties of Mono and Inyo, as well as parts of Modoc, Lassen, Sierra, Nevada, Placer, El Dorado, Alpine, Kern, Los Angeles, and San Bernardino Counties. Although portions of most drainage basins of the Lahontan Area lie in Nevada, tabulations in this bulletin are limited to the areas within the State of California. Among the principal cities and urban communities are Lancaster, Palmdale, Mojave, Barstow, Victorville, Bishop, Bridgeport, Truckee, and Susanville.

In order to facilitate the present studies, the Lahontan Area was subdivided into 12 hydrographic units, the boundaries of which lie on the watershed divides of the principal streams or interior drainage basins, as shown on Plate 8. Table 126 lists the 12 hydrographic units and their areas, and Table 127 presents the areas of the portion of each county included within the Lahontan Area. The water surface area of Lake Tahoe, which lies in Hydrographic Unit 4 and in the Counties of Placer and El Dorado, is not included in the tabulations.

TABLE 126

AREAS OF HYDROGRAPHIC UNITS, LAHONTAN AREA

Hydrographic unit		Acres
Reference number	Name	
1	Surprise	505,000
2	Madeline Plains	486,000
3	Honey Lake	1,499,000
4	Truckee River	428,000*
5	Carson River	287,000
6	Walker River	582,000
7	Mono Lake	438,000
8	Adobe Valley	188,000
9	Owens River	2,005,000
10	Death Valley	9,868,000
11	Mojave River	3,140,000
12	Antelope Valley	1,546,000
	APPROXIMATE TOTAL	20,970,000

* Does not include water surface area of Lake Tahoe.

TABLE 127

AREAS OF COUNTIES WITHIN BOUNDARIES OF LAHONTAN AREA

County	Acres
Alpine	305,000
El Dorado	109,000*
Inyo	6,486,000
Kern	1,624,000
Lassen	2,116,000
Los Angeles	723,000
Modoc	468,000
Mono	2,009,000
Nevada	114,000
Placer	120,000*
San Bernardino	6,761,000
Sierra	138,000
APPROXIMATE TOTAL	20,970,000

* Does not include water surface area of Lake Tahoe.

The climate of the Lahontan Area varies as widely as its topography, which ranges from the lofty rugged crags along the Sierra Nevada crest to the plateaus of Madeline Plains, the deeply incised Owens Valley, and the arid expanse of the Mojave Desert. Mount Whitney and Death Valley, within 90 miles of each other, are the highest and lowest spots in the United States, emphasizing the contrast common to this area. The highest temperature recorded in the United States was 134° F. at Greenland Ranch in Death Valley in July, 1913. Winter temperatures below 0° F. are common in the Sierra Nevada and the northern valleys and plateaus. The mean seasonal depth of precipitation varies from a maximum of about 50 inches in the high elevations of the Sierra Nevada to 1.7 inches or possibly less in portions of the desert regions. Snowfall is characteristic of the mountains and high plateaus and valleys during winter. Generally, some 75 per cent of seasonal precipitation occurs from November through April. Although precipitation in the desert is light, local thunderstorms have been known to contribute much more than the equivalent of average seasonal precipitation to local areas in less than two hours.

The estimated mean seasonal natural runoff of streams in the Lahontan Area is about 3,177,000 acre-feet, or about 4.5 per cent of that for the entire state. The principal streams are the Susan, Truckee, Carson, Walker, and Owens Rivers, draining the easterly slopes of the Sierra Nevada, and the Mojave

River, draining the northeasterly slopes of the San Bernardino Mountains. Streams in the desert portions of the area are ephemeral in nature. A substantial amount of the runoff from the Sierra Nevada is derived from snowmelt of late spring and early summer.

A relatively small amount of water is imported to the Lahontan Area and stored in Tule Reservoir, located in the Madeline Plains Hydrographic Unit. This water comes from Cedar Creek, a tributary of the Pit River in the Central Valley Area, and is used for irrigation of grain and as a water supply for waterfowl ponding areas operated by the California Department of Fish and Game. Reservoir storage records indicate an average seasonal import of about 11,000 acre-feet. An average of some 7,000 acre-feet of water has been exported from the Lahontan Area seasonally since about 1870 from the Little Truckee River, for irrigation use in Sierra Valley in the Central Valley Area. Also, about 2,000 acre-feet of water are diverted seasonally from Echo Lake in the Truckee River Hydrographic Unit, for hydroelectric power generation in the American River Basin of the Central Valley Area.

The major export of water from the Lahontan Area is that which is carried by the Los Angeles Aqueduct to the South Coastal Area. The City of Los Angeles diverts water in the Mono Lake Hydrographic Unit and transports it by tunnel to the headwaters of the Owens River. The Los Angeles Aqueduct, diverting waters of both the Mono Lake and Owens River Hydrographic Units, then conveys the waters by conduit some 233 miles to the City of Los Angeles, where it is distributed and used. The capacity of the aqueduct, about 320,000 acre-feet seasonally, presently limits this export from the Lahontan Area.

As shown on Plate 4, a total of 58 valley fill areas, which may or may not contain usable ground water, has been identified in the Lahontan Area. Only those in the Owens, Antelope, Mojave, and Indian Wells Valleys have been extensively developed by wells, the water being used principally for irrigation. Thirty-eight of the foregoing valley fill areas each cover more than 100 square miles.

Population in the Lahontan Area is characteristically sparse and widely scattered, and cities and urban communities are relatively small. However, population growth during recent years has generally kept pace with the phenomenal rates experienced in other parts of the State. The most notable recent increases in permanent population have occurred in and around Barstow and Lancaster in the southerly portion of the area. In these localities the advent of major military and related aircraft industrial installations has produced an influx of resident civilians, who either assist in operation of the installations or are employed in business ventures catering to the demands of the increased military and civilian population. In addition to the foregoing, there has been a large increase in seasonal population of the recreational areas in the vicinity of Lake Tahoe, and in the Owens Valley and Mono Basin. This increase has been far greater proportionately than the increase in permanent residents in these predominantly recreational localities. Table 128 shows the increase in population of four representative urban communities from 1940 to 1950, as well as three representative unincorporated urban centers. Many of the more important urban centers in the area are unincorporated and without definite boundaries.

TABLE 128

POPULATION OF PRINCIPAL URBAN CENTERS, LAHONTAN AREA

City	1940			1950		
	Within city limits	In suburbs	Total	Within city limits	In suburbs	Total
Barstow	2,100		2,100	6,100	4,300	10,400
Susanville	1,600	3,600	5,200	5,300	1,700	7,000
Bishop	1,500	1,500	3,000	2,900	2,800	5,700
Victorville	2,000		2,000	3,200		3,200
Lancaster*			2,100			3,600
Mojave*			1,200			2,100
Truckee*			700			1,000

* Unincorporated areas.

Agriculture is the major economic activity of the Lahontan Area, and the raising of livestock predominates. In the mountain valleys where surface diversion of water proved to be practicable, as well as in other valley areas where ground water supplies were found to be available, the lands have been developed to irrigated agriculture. However, since about 1920 the aggregate irrigated acreage has remained substantially unchanged. In the high valley irrigation developments, which are characteristic of the northern portion of the Lahontan Area, the majority of the irrigated lands has been devoted to pasture-type crops. Field crops have prevailed where irrigation water is available along the Mojave River and in Antelope Valley.

The water supply development of the Lahontan Area has been closely allied to the demands of irrigation. Early settlers diverted the flow of surface streams to water their forage crops. Diversions from the Mojave River were first recorded in 1872, and this was followed by accelerated activities of land development companies and promotional agencies in the area. Apart from such surface diversions, a supply of ground water was developed in lower

Antelope Valley around 1880, from flowing wells which were drilled to depths of between 200 and 500 feet. The introduction of electric power to Antelope Valley in 1914 resulted in a major increase in the use of ground water for irrigation. The rate of pumping has accelerated to this date, with attendant severe lowering of ground water levels.

The fertile lands of the Owens Valley were first developed by settlers in the late 1860's. By 1910 some 50,000 acres were under irrigation, almost exclusively from surface water sources, the principal crops being alfalfa, pasture, and decidous fruits. An artesian well was drilled at Keeler in 1902, but because of a large content of hydrogen sulphide the water was not used for domestic purposes. Several other artesian wells were drilled in the vicinity during the next few years, with unsatisfactory results. Other than the water obtained from small domestic and stockwatering wells, ground water received little attention in the valley for many years, due to the ample surface supplies readily available. By 1907 the growth of the City of Los Angeles made search for an additional water supply imperative. As a result, the city undertook construction of the then unprecedented Los Angeles Aqueduct, and by 1913 had started acquiring and conveying to its service area in the South Coastal Area a major portion of the available water supplies in the Owens Valley. Development of the waters of the Mono Basin by the City of Los Angeles was completed in 1940. These large exports have virtually eliminated irrigated agriculture in the economy of the Owens Valley and Mono Basin. During the drought years of the early 1930's the city drilled a number of wells in the extensive ground water basins underlying the Owens Valley, and for a few years pumped a substantial amount of water for export from that source.

Commencing in the latter decades of the last century, the waters of the Truckee, Carson, and Walker Rivers have been developed to create an important agricultural and stockraising economy in both California and Nevada. Among the larger of such irrigation developments within California are those along the East and West Walker Rivers.

As has been stated, in this century there has been little change in the total irrigated acreage in the Lahontan Area. Increases in irrigated agriculture in the southerly portion, comprising Antelope and Mojave Valleys, have been counterbalanced by marked decreases in the Owens Valley and Mono Basin, resulting from the cited export by the City of Los Angeles.

The 82 reservoirs presently constructed in the Lahontan Area have an aggregate storage capacity of some 1,400,000 acre-feet, of which over 700,000 acre-feet are provided by the high-level storage in Lake Tahoe. The principal reservoirs are listed below.

Reservoir	*Stream*	*Hydrographic unit*	*Storage capacity, in acre-feet*
Tule Lake	Cedar Creek	Madeline Plains	39,500
McCoy Flat	Susan River	Honey Lake	17,300
Lake Tahoe	Truckee River	Truckee River	732,000
Boca	Little Truckee River	Truckee River	41,200
Donner	Donner Creek	Truckee River	11,000
Independence	Independence Creek	Truckee River	18,500
Topaz	West Walker River	Walker River	59,000
Bridgeport	East Walker River	Walker River	42,000
Grant Lake	Rush Creek	Mono Lake	47,500
Long Valley	Owens River	Owens River	184,000
Tinemaha	Owens River	Owens River	16,600
Haiwee	Owens River	Owens River	60,000

Reservoirs in the Truckee River Basin, and Topaz and Bridgeport Reservoirs on the Walker, are largely used to conserve and regulate irrigation water supplies for lands in both California and Nevada. The reservoirs in the Truckee River Hydrographic Unit are operated coordinately for irrigation, hydroelectric power generation, and municipal uses. The last four reservoirs listed in the tabulation provide regulation for a municipal water supply for the City of Los Angeles. This water is also utilized for power development along the route of the aqueduct to terminal storage in the San Fernando Valley of the South Coastal Area. In addition to the principal reservoirs listed in the foregoing tabulation, there are a number of small storage developments in the Lahontan Area. Several in the Mono Lake and Owens River Hydrographic Units are essentially for the purpose of regulation of water for hydroelectric power generation. Most of the remaining small reservoirs serve to regulate irrigation water supplies.

The lack of adequate firm water supplies has limited expansion of the irrigated acreage in the Lahontan Area. It is probable, however, that in the future additional diversified irrigated crops will be produced, particularly in the Mojave River and Antelope Valleys, utilizing water expected to be imported into those areas. In addition, there will probably be further development of local water supplies in the northerly portion of the area, and attendant increase in irrigated agriculture. Present urban centers dependent upon agriculture will expand, and new urban centers will come into being to supply services and materials in the vicinity of the new agricultural developments. Urban centers supported largely by military or industrial installations may also experience growth in the future. A compilation of the principal water service agencies in the Lahontan Area, together with the number of domestic services and irrigated acres served by each agency, is included in Appendix B.

Outstanding scenic attractions and a climate favorable to winter and summer sports activity have combined to make relatively large portions of the Lahontan Area extremely attractive to vacationists, sportsmen, and tourists. The lands around Lake Tahoe

Scene Near Susanville

Courtesy Eastman's Studio

The Sierra Nevada

Courtesy State Division of Highways

and many other areas along the easterly slopes of the Sierra Nevada provide desirable locations for the summer homes of residents of other parts of California. Many resorts, motels, and camp grounds also provide facilities for the recreation-seeking public. During the winter season the snow-covered slopes of the Sierra Nevada attract a growing number of winter sports enthusiasts each year. The Tahoe, Toiyabe, and Inyo National Forests serve visitors interested in the excellent facilities for hunting, fishing, hiking, and camping. A number of alpine areas remain in a primitive state and can be reached only by foot or by pack train. Death Valley is nationally recognized as a unique winter vacation area. Due to the opportunities offered, both in healthful surroundings and in meeting the increasing demands of visitors to the region, it is probable that these recreational areas, aided by improved transportation and communication facilities, will attract a larger percentage of permanent residents in the future. Of the water requirements imposed by the recreational facilities of the Lahontan Area, that related to the preservation and propagation of fish and wildlife is the most significant. The aggregate use of water by summer homes, resorts, and camps is small and largely of a domestic nature. However, much of the recreational value of the area is dependent upon maintenance of adequate stream flows and lake levels to assure perpetuation of fish and wild fowl. It is anticipated that water supply development primarily for these purposes will occur in the future.

Military lands in the Lahontan Area, situated largely in the southern portion, are predominantly used for experimental and training purposes. Only minor parts of the total area of the military reservations actually receive water service, which water is generally used for domestic or allied purposes. It is considered probable that, barring another major war, the military establishment will in the future stabilize at about the present level.

Exploitation of the great Comstock Lode at Virginia City in Nevada in the 1860's was directly responsible for early development nearby in the Lahontan Area. Mining activity in the Lahontan Area itself commenced shortly after the Comstock discovery, and has continued to be of economic significance to the present day, with sporadic interruptions due to fluctuating market conditions. Extensive tungsten deposits are now being mined in the vicinity of Bishop. Borax mining is carried on near Kramer and in the Owens Lake and Searles Lake areas. Tungsten and manganese are found in the desert area between Randsburg and the eastern boundary of the State. Various other minerals of commercial importance are found in scattered locations throughout the Lahontan Area, notably sulphur in the Carson River Basin, lead in the Darwin area, and limestone, from which cement is manufactured, in the vicinity of Victorville and Monolith. An important discovery of the group of minerals known as "rare earth elements" and radioactive thorium was made in the southeastern portion of the Lahontan Area in 1951, and these deposits are presently under development. The water requirements of the mining industry in the Lahontan Area are quite small as related to the total requirement for water. Available information indicates that future mining activities probably will maintain at about the present level, and that the aggregate ultimate water requirement related to mining will impose only a minor demand on the developed water supplies.

The timber and lumber manufacturing industries constituted an important segment of the economy of the Lahontan Area in the early days, largely in connection with the demands of nearby mines and railroads. However, extensive exploitation of the timber resource has caused it to decrease in importance, a position that will probably be maintained in the future. The principal present centers for the timber industry are Bishop, Hobart Mills, and Susanville. The aggregate consumptive water requirement for maintenance of this industry at the present time is relatively small, and is not expected to impose a significant demand on the developed water supplies of the area in the future.

In summary, it should be emphasized that water is developed and utilized in the Lahontan Area primarily for the production of agricultural crops, and to a lesser extent for municipal purposes, including a substantial export to Los Angeles. It is anticipated that this predominance of the water requirement for irrigation will maintain in the future. Domestic uses of water, including that by recreational developments, while important to the economy of the area, is now and will continue to be small in amount. This is also true of the water requirement of industries other than in urban centers, including mining and lumbering. There is a considerable hydroelectric power development in the area, and a potential for additional future development of this nature. Water is not employed for navigation, other than the incidental use for that purpose in connection with recreational boating on Lake Tahoe and other lakes and reservoirs. Some minor flood control projects have been constructed, and as the country develops flood control may become of increasing importance. With the anticipated continued growth of the State, and the consequent increase in demand for recreational facilities, it is probable that additional water supplies will be developed and utilized for this purpose, including the waters necessary for the preservation and propagation of fish and wildlife.

There follows a presentation of available data and estimates pertinent to the nature and extent of water requirements in the Lahontan Area, both at the present time and under conditions of probable ultimate development.

PRESENT WATER SERVICE AREAS

As a necessary step in estimating the amount of the water requirement in the Lahontan Area, determinations were made of the location, nature, and extent of present irrigated and urban and suburban water service areas. Remaining lands were not classified in detail with regard to their relatively minor miscellaneous types of water service, although such water service was given consideration in estimating the present water requirement.

Irrigated Lands

It was determined that under present conditions of development in the Lahontan Area, about 228,000 acres are irrigated in a given year, on the average. This constitutes approximately three per cent of the land irrigated throughout California.

Alfalfa is the dominant irrigated crop in the Lahontan Area, occupying over 40 per cent of all the irrigated lands. Pasture is next in importance, followed by hay and grain. Most of the alfalfa is grown in Antelope Valley in the southern portion of the area, while the irrigated pasture and grain are found largely in the northern portion. Most of the alfalfa grown in Antelope Valley is cut for hay for sale in the vicinity of Los Angeles. The irrigated pasture and hay and grain are utilized locally in connection with the livestock industry, which predominates in the northern portion of the area.

The field surveys upon which determinations of irrigated acreage in the Lahontan Area were based were accomplished during the period from 1947 through 1950, by several agencies and with varying standards and degrees of accuracy. Information on the irrigated crops in some of the northern hydrographic units was supplied by the watermasters maintained by the State Division of Water Resources in those areas. Information regarding the dates and scales of field mapping and sources of data is contained in Appendix E. There follows a list of the various crop groups into which irrigated lands of the Lahontan Area were classified, with a view to segregating those of similar water use:

Alfalfa	Hay, seed, and pasture
Pasture	Grass and legumes, other than alfalfa, used for livestock forage
Orchard	Deciduous fruit and nuts
Truck crops	Intensively cultivated fresh vegetables
Miscellaneous field crops	Corn, sunflowers, and rape
Hay and grain	All grains, and cultivated and wild hay

It is estimated that approximately 2,800 acres in the Lahontan Area are occupied by farm lots at the present time. These consist of farm buildings and the immediately adjacent yards and gardens receiving water service.

In the West Walker River Basin, a portion of the Walker River Hydrographic Unit, some 8,600 acres were planted to irrigated crops at the time the field surveys were accomplished. However, in years when the unregulated water supply is adequate, approximately 14,000 acres are irrigated in this basin, resulting in a total presently irrigated area of about 26,000 acres in the entire hydrographic unit.

Summaries of presently irrigated acreages within the Lahontan Area by the various crop groups are presented in Tables 129 and 130. Table 129 lists the acreages by hydrographic units, and Table 130 by counties.

Urban and Suburban Water Service Areas

It was determined that under present conditions of development in the Lahontan Area approximately 10,000 acres are devoted to urban and suburban types of land use. For the most part, the business, commercial, and industrial establishments, and surrounding homes included in this areal classification receive a municipal type of water supply. Areas of urban and suburban water service within each hydrographic unit of the Lahontan Area are listed in Table 131, and within each county in Table 132. It should be noted that the areas shown are gross acreages, as they include streets and intermingled undeveloped lands that are a part of the urban type of community.

Unclassified Areas

Remaining lands in the Lahontan Area, other than those that are irrigated or urban and suburban in character, were not classified in detail as regards present water service. Of a total of about 20,730,000 acres of such remaining lands, less than 5,000 acres actually receive water service at the present time. These relatively minor service areas consist of scattered developed portions of national forests and monuments, public beaches and parks, private recreational areas, military reservations, etc.

Portions of 10 national forests, occupying some 2,444,000 acres, lie within the Lahontan Area. In general, these federal forest reserves are situated in the more mountainous regions, including most of the easterly slopes of the Sierra Nevada, the White and Inyo Mountains on the east side of the Owens Valley, and the easterly slopes of the San Gabriel and San Bernardino Mountains in the south. About 17,000 acres of national forest lands are presently irrigated, which acreage is included in the values listed in Tables 129 and 130. Most of this irrigation is practiced in mountain valleys, mainly for the culture of irrigated pasture. Within the national forest there

TABLE 129

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, LAHONTAN AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Orchard	Truck crops	Miscellaneous field crops	Hay and grain	Net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
1	Surprise Valley	6,300	21,000	300	100	0	13,500	41,200	500	800	42,500
2	Madeline Plains	700	5,800	100	0	0	1,000	7,600	100	200	7,900
3	Honey Lake	8,700	14,700	0	100	0	14,700	38,200	500	800	39,500
4	Truckee River	0	2,000	0	0	0	0	2,000	0	100	2,100
5	Carson River	200	7,500	0	0	100	300	8,100	100	200	8,400
6	Walker River	200	19,900	0	0	100	600	20,800	300	400	21,500
7	Mono Lake	0	2,000	0	0	0	0	2,000	0	100	2,100
8	Adobe Valley	0	2,300	0	0	0	0	2,300	0	100	2,400
9	Owens River	4,800	4,600	200	200	0	100	9,900	100	200	10,200
10	Death Valley	5,700	100	100	1,600	1,600	1,700	10,800	100	200	11,100
11	Mojave River	7,500	1,700	400	2,100	0	1,900	13,600	200	300	14,100
12	Antelope Valley	62,100	100	4,500	100	200	4,200	71,200	900	1,500	73,600
	APPROXIMATE TOTALS	96,200	81,700	5,600	4,200	2,000	38,000	228,000	2,800	4,900	236,000

TABLE 130

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN COUNTIES, LAHONTAN AREA

(In acres)

County	Alfalfa	Pasture	Orchard	Truck crops	Miscellaneous field crops	Hay and grain	Net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
Alpine	200	7,500	0	0	100	300	8,100	100	200	8,400
El Dorado	0	600	0	0	0	0	600	0	0	600
Inyo	3,700	1,600	200	900	0	100	6,500	100	100	6,700
Kern	7,200	100	0	1,000	900	1,600	10,800	300	300	11,400
Lassen	9,400	20,900	100	100	0	15,800	46,300	600	1,000	47,900
Los Angeles	54,900	100	4,400	0	100	2,000	61,500	500	1,300	63,300
Modoc	6,300	20,500	300	100	0	13,500	40,700	500	800	42,000
Mono	1,300	27,300	100	0	100	500	29,300	300	600	30,200
Nevada	0	200	0	0	0	0	200	0	0	200
Placer	0	0	0	0	0	0	0	0	0	0
San Bernardino	13,200	1,700	500	2,100	800	4,200	22,500	400	500	23,400
Sierra	0	1,200	0	0	0	0	1,200	0	100	1,300
APPROXIMATE TOTALS	96,200	81,700	5,600	4,200	2,000	38,000	228,000	2,800	4,900	236,000

are administration buildings, public camps, trailer parks, and other accommodations for tourists, but the actual water service area involved in these features is small.

The Division of Beaches and Parks of the State Department of Natural Resources administers three public beaches and parks in the Lahontan Area, all located in the vicinity of Lake Tahoe. These recreational areas aggregate about 1,300 acres, but water service consists primarily of domestic supplies for permanent buildings and surrounding grounds, and summer water supplies for camp grounds and picnic areas. Death Valley National Monument, under the jurisdiction of the National Park Service, occupies 1,735,000 acres in Inyo and San Bernardino Counties. Areas presently having water service in Death Valley are small, and are mostly in the vicinity of Furnace Creek and Stove Pipe Wells.

The greatest concentration of private recreational developments within the Lahontan Area is in the vicinity of Lake Tahoe, but scattered resorts and camps extend southward along the Sierra Nevada from Lake Tahoe to the southern end of the Owens Valley. Their greatest use is in the summer months, but many also cater to winter sport enthusiasts. The aggregate water service area is probably less than 5,000 acres.

The area of military establishments within the Lahontan Area totals about 2,008,000 acres, located mainly in the southern portion of the area. In general, the reservations consist of the base installation, including quarters and administration buildings, and large areas of undeveloped land utilized for training and experimental purposes.

Summary

Table 131 comprises a summary of present water service areas within hydrographic units of the Lahontan Area. A similar summary for counties of the area is presented in Table 132.

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TABLE 131

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS, LAHONTAN AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands	Urban and suburban areas	Approximate total
1	Surprise Valley	42,500	400	42,900
2	Madeline Plains	7,900	20	7,920
3	Honey Lake	39,500	2,000	41,500
4	Truckee River	2,100	3,200	5,300
5	Carson River	8,400	30	8,430
6	Walker River	21,500	30	21,530
7	Mono Lake	2,100	20	2,120
8	Adobe Valley	2,400	0	2,400
9	Owens River	10,200	700	10,900
10	Death Valley	11,100	1,100	12,200
11	Mojave River	14,100	1,700	15,800
12	Antelope Valley	73,600	1,100	74,700
	Subtotals	236,000	10,300	246,000
	Unclassified areas receiving water service			4,500
	APPROXIMATE TOTAL			250,000

TABLE 132

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN COUNTIES, LAHONTAN AREA

(In acres)

County	Irrigated lands	Urban and suburban areas	Approximate total
Alpine	8,400	30	8,430
El Dorado	600	1,600	2,200
Inyo	6,700	700	7,400
Kern	11,400	800	12,200
Lassen	47,900	2,000	49,900
Los Angeles	63,300	900	64,200
Modoc	42,000	400	42,400
Mono	30,200	70	30,270
Nevada	200	200	400
Placer	0	1,400	1,400
San Bernardino	23,400	2,200	25,600
Sierra	1,300	0	1,300
Subtotals	236,000	10,300	246,000
Unclassified areas receiving water service			4,500
APPROXIMATE TOTAL			250,000

PROBABLE ULTIMATE WATER SERVICE AREAS

To aid in estimating the amount of water that ultimately will be utilized in the Lahontan Area, projections were first made to determine the probable ultimate irrigated and urban and suburban water service areas. It was assumed that the remaining lands, for convenience referred to as "other water service areas," ultimately will be served with water commensurate with their needs.

Irrigated Lands

Based on data from land classification surveys, it was estimated that a gross area of approximately 3,098,000 acres in the Lahontan Area is suitable for irrigated agriculture. The field classification of lands of the Mojave River Hydrographic Unit was supplemented with laboratory determinations of moisture-holding capacities of soil samples taken from representative areas throughout the desert. This was done because it was found that the moisture-holding capacity, rather than depth of soil or topographic conditions, was generally the limiting factor in determining irrigability of the lands.

Excepting farm lots and certain lands within the gross area that experience indicates will never be served with water, such as lands occupied by roads, railroads, etc., it was estimated that under ultimate conditions of development a net area of approxi-

TABLE 133

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, LAHONTAN AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
1	Surprise Valley	102,000	2,000	11,300	88,700
2	Madeline Plains	157,000	3,100	18,900	135,000
3	Honey Lake	259,000	5,200	35,800	218,000
4	Truckee River	32,300	600	5,400	26,300
5	Carson River	16,600	300	3,000	13,300
6	Walker River	43,400	900	3,900	38,600
7	Mono Lake	13,400	400	1,600	11,400
8	Adobe Valley	25,300	500	3,700	21,100
9	Owens River	159,000	3,200	21,700	134,000
10	Death Valley	1,050,000	21,000	147,000	882,000
11	Mojave River	523,000	10,500	78,200	434,000
12	Antelope Valley	717,000	8,600	98,900	610,000
	APPROXIMATE TOTALS	3,098,000	56,300	430,000	2,612,000

TABLE 134

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN COUNTIES, LAHONTAN AREA

(In acres)

County	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
Alpine	16,600	300	3,000	13,300
El Dorado	9,500	200	1,400	7,900
Inyo	217,000	4,300	30,200	182,000
Kern	507,000	8,400	70,800	428,000
Lassen	413,000	8,300	54,100	351,000
Los Angeles	427,000	4,400	59,800	363,000
Modoc	98,300	1,900	10,900	85,500
Mono	135,000	2,800	16,000	116,000
Nevada	12,400	200	2,300	9,900
Placer	700	0	100	600
San Bernardino	1,245,000	25,200	178,000	1,042,000
Sierra	16,300	300	2,600	13,400
APPROXIMATE TOTALS	3,098,000	56,300	430,000	2,612,000

TABLE 135

PROBABLE ULTIMATE PATTERN OF IRRIGATED CROPS, LAHONTAN AREA

(In acres)

Hydrographic unit		Alfalfa	Pasture	Orchard	Nuts	Vineyard	Truck crops	Sugar beets	Miscellaneous field crops	Hay and grain	Approximate total
Reference number	Name										
1	Surprise Valley	17,700	36,100	0	0	0	0	1,600	0	33,300	88,700
2	Madeline Plains	2,500	88,600	0	0	0	0	0	0	44,000	135,000
3	Honey Lake	32,000	92,700	0	0	0	0	3,100	0	90,100	218,000
4	Truckee River	0	16,900	0	0	0	0	0	0	9,400	26,300
5	Carson River	1,000	8,700	0	0	0	0	800	0	2,800	13,300
6	Walker River	500	21,300	0	0	0	0	0	6,200	10,600	38,600
7	Mono Lake	500	9,300	0	0	0	0	0	0	1,600	11,400
8	Adobe Valley	1,000	8,800	0	0	0	0	2,000	0	9,300	21,100
9	Owens River	30,300	37,300	8,000	1,000	12,400	0	6,400	0	39,000	134,000
10	Death Valley	155,000	302,000	9,200	2,000	18,000	17,200	13,500	0	365,000	882,000
11	Mojave River	182,000	90,300	4,700	0	11,300	15,300	10,400	0	120,000	434,000
12	Antelope Valley	225,000	142,000	17,300	0	13,100	20,700	17,300	100	174,000	610,000
	APPROXIMATE TOTALS	647,000	854,000	39,200	3,000	54,800	53,200	55,100	6,300	899,000	2,612,000

mately 2,612,000 acres will actually be irrigated. Table 133 presents these estimates for hydrographic units of the Lahontan Area, and Table 134 for the various counties. The probable ultimate crop pattern for irrigated lands of the Lahontan Area is presented in Table 135. The crop grouping parallels that used in the case of present development, except for the added groups titled "Nuts," "Vineyards," and "Sugar beets." These groups are of minor importance and were not segregated in the case of the present crop pattern, but are expected to be of greater significance in the future.

Urban and Suburban Water Service Areas

While it is expected that urban and suburban growth in the Lahontan Area generally will be associated with further development of agriculture, the scenic attractions and recreational opportunities will also influence the growth of certain population centers. Population increase may also be brought about by expansion of industries, including manufacturing and those related to mining, and possibly by further development of military installations. It was estimated that under ultimate conditions of development the urban and suburban water service areas will have increased to approximately 54,000 acres. In general, urban and suburban types of land use are expected to occupy the same localities as at present, but vacant lands will be filled and densities increased. In addition, some future development of new urban areas to conform with new irrigated agricultural areas is considered to be probable. It was forecast that such urban encroachment on lands surrounding present population centers and on new lands will amount to about 43,000 acres ultimately. For the purposes of the present studies no attempt was made to delineate the boundaries of such encroachment, nor to determine what proportion will be on irrigable lands. The estimate of probable ultimate urban and suburban water service areas is included in Table 137. It should be noted that the areas shown are gross acreages, including streets, vacancies, etc.

Other Water Service Areas

Remaining lands of the Lahontan Area, not classified as irrigable or urban and suburban under conditions of ultimate development, aggregate about 17,820,000 acres, or 85 per cent of the area. As previously mentioned, it was assumed that ultimately these lands will be served with water in amounts sufficient for their needs. No attempt was made to segregate these "other water service areas" in detail in regard to the nature of their probable ultimate water service. However, as shown in Table 136, they were broken down for convenience in estimating water requirements into those portions inside and outside of national forests, monuments, and military reservations, and above and below an elevation of 3,000 feet. The lands classified as "other water service areas" include recreational developments, both public and private, military establishments, residential and industrial types of land use outside of urban communities, etc. By far the greater portion of the lands are situated in rough mountainous terrain and barren desert waste. It is expected that even under conditions of ultimate development this large portion will be only sparsely settled, and will have only very minor requirements for water service.

Summary

Table 137 comprises a summary of probable ultimate water service areas, segregated into irrigable lands, urban and suburban areas, and other water service areas.

TABLE 136

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, LAHONTAN AREA

(In acres)

Hydrographic unit		Inside national forests, monuments, and military reservations		Outside national forests, monuments, and military reservations		Approximate total
Reference number	Name	Above 3,000-foot elevation	Below 3,000-foot elevation	Above 3,000-foot elevation	Below 3,000-foot elevation	
1	Surprise Valley	122,000	0	280,000	0	402,000
2	Madeline Plains	24,800	0	302,000	0	327,000
3	Honey Lake	303,000	0	933,000	0	1,236,000
4	Truckee River	270,000	0	103,000	0	373,000
5	Carson River	257,000	0	13,400	0	270,000
6	Walker River	409,000	0	129,000	0	538,000
7	Mono Lake	229,000	0	195,000	0	424,000
8	Adobe Valley	115,000	0	47,500	0	163,000
9	Owens River	1,025,000	0	819,000	0	1,844,000
10	Death Valley	2,074,000	884,000	2,896,000	2,954,000	8,808,000
11	Mojave River	170,000	145,000	725,000	1,572,000	2,612,000
12	Antelope Valley	19,200	140,000	343,000	320,000	822,000
	APPROXIMATE TOTALS	5,018,000	1,169,000	6,786,000	4,846,000	17,820,000

TABLE 137

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS, LAHONTAN AREA

(In acres)

Hydrographic unit		Irrigable lands	Urban and suburban areas	Other water service areas	Approximate total
Reference number	Name				
1	Surprise Valley	102,000	1,000	402,000	505,000
2	Madeline Plains	157,000	1,500	327,000	486,000
3	Honey Lake	259,000	3,700	1,236,000	1,499,000
4	Truckee River	32,300	22,700	373,000	428,000
5	Carson River	16,600	200	270,000	287,000
6	Walker River	43,400	400	538,000	582,000
7	Mono Lake	13,400	200	424,000	438,000
8	Adobe Valley	25,300	200	163,000	188,000
9	Owens River	159,000	2,100	1,844,000	2,005,000
10	Death Valley	1,050,000	9,800	8,808,000	9,868,000
11	Mojave River	523,000	5,100	2,612,000	3,140,000
12	Antelope Valley	717,000	6,800	822,000	1,546,000
	APPROXIMATE TOTALS	3,098,000	53,700	17,820,000	20,970,000

UNIT VALUES OF WATER USE

Studies of unit values of water use in the Lahontan Area were conducted largely by reviewing published information applicable to the area, and by correlating experimental data obtained from other similar areas. The estimates so obtained were modified by standard methods to provide complete coverage of the area.

Irrigation Water Use

In general, unit seasonal values of consumptive use of water on lands devoted to the various irrigated crops were computed by the methods outlined in Chapter II. The wide climatic variations over the Lahontan Area have a marked effect upon consumptive use of water, and more particularly on the amount of water that must be applied to mature irrigated crops. A seasonal variance of more than one foot in depth of applied water may occur between similar crops grown in the northern portions of the area and in the southern portions. The cooler climate, higher precipitation, and shorter growing season of the northern hydrographic units tend to reduce the quantity of applied water necessary for plant growth. Table 138 presents the estimated unit values of mean seasonal consumptive use of applied irrigation water and of precipitation on lands devoted to crops of the various groups.

Unit mean seasonal consumptive use of applied water on farm lots was estimated to be about 0.5 foot in depth. The estimates of unit mean seasonal consumptive use of precipitation on farm lots varied from 0.4 to 1.1 feet in the various hydrographic units of the Lahontan Area. The estimated unit values were used in determining consumptive use of applied water for both the present and probable ultimate water service areas.

Urban and Suburban Water Use

Unit mean seasonal values of use of water on urban and suburban water service areas of the Lahontan Area were estimated on the basis of available records of delivery of water to the areas, as compiled by municipalities and other public water service agencies. Probable ultimate values of water deliveries were estimated by applying to the present values derived percentage factors to account for expected future increase in population densities and in per capita water use. Table 139 presents the estimates of present and probable ultimate unit seasonal values of gross water deliveries to and consumptive use of water on urban and suburban water service areas.

TABLE 138

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, LAHONTAN AREA

(In feet of depth)

Hydrographic unit		Alfalfa			Pasture			Orchard			Nuts			Vineyard		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Surprise Valley	1.7	0.9	2.6	1.8	0.8	2.6	1.2	0.9	2.1	--	--	--	--	--	--
2	Madeline Plains	1.5	1.1	2.6	1.7	0.9	2.6	1.1	1.1	2.2	--	--	--	--	--	--
3	Honey Lake	2.3	1.1	3.4	2.3	1.1	3.4	1.6	1.1	2.7	--	--	--	--	--	--
4	Truckee River	--	--	--	1.6	0.8	2.4	--	--	--	--	--	--	--	--	--
5	Carson River	1.4	1.3	2.7	1.4	1.1	2.5	--	--	--	--	--	--	--	--	--
6	Walker River	1.6	0.9	2.5	1.5	0.9	2.4	--	--	--	--	--	--	--	--	--
7	Mono Lake	1.2	1.2	2.4	1.4	0.9	2.3	--	--	--	--	--	--	--	--	--
8	Adobe Valley	1.6	0.9	2.5	1.5	0.8	2.3	--	--	--	--	--	--	--	--	--
9	Owens River	2.0	0.6	2.6	1.8	0.6	2.4	1.5	0.6	2.1	1.5	0.6	2.1	1.1	0.6	1.7
10	Death River	3.0	0.4	3.4	2.8	0.4	3.2	2.2	0.4	2.6	2.2	0.4	2.6	2.4	0.4	2.8
11	Mojave River	2.8	0.4	3.2	2.7	0.4	3.1	2.1	0.4	2.5	--	--	--	2.3	0.4	2.7
12	Antelope Valley	3.0	0.6	3.6	2.8	0.6	3.4	2.2	0.6	2.8	--	--	--	2.4	0.6	3.0

TABLE 138—Continued

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, LAHONTAN AREA

(In feet of depth)

Hydrographic unit		Truck crops			Sugar beets			Miscellaneous field crops			Hay and grain		
Reference number	Name	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total	Applied water	Precipitation	Total
1	Surprise Valley	0.6	0.9	1.5	0.9	0.9	1.8	--	--	--	1.0	0.9	1.9
2	Madeline Plains	--	--	--	--	--	--	--	--	--	1.0	1.0	2.0
3	Honey Lake	0.8	1.1	1.9	1.1	1.0	2.1	--	--	--	0.8	1.0	1.8
4	Truckee River	--	--	--	--	--	--	--	--	--	0.5	0.9	1.4
5	Carson River	--	--	--	0.8	1.2	2.0	0.8	1.2	2.0	0.5	1.0	1.5
6	Walker River	--	--	--	--	--	--	0.9	0.9	1.8	0.9	0.9	1.8
7	Mono Lake	--	--	--	--	--	--	--	--	--	0.7	1.1	1.8
8	Adobe Valley	--	--	--	0.9	0.9	1.8	--	--	--	0.9	0.9	1.8
9	Owens River	1.4	0.6	2.0	1.2	0.6	1.8	--	--	--	1.2	0.6	1.8
10	Death Valley	1.6	0.4	2.0	2.2	0.4	2.6	1.6	0.4	2.0	1.1	0.4	1.5
11	Mojave River	1.5	0.4	1.9	2.2	0.4	2.6	--	--	--	0.9	0.4	1.3
12	Antelope Valley	1.4	0.6	2.0	2.0	0.6	2.6	1.5	0.6	2.1	0.8	0.6	1.4

Use of Water in Other Water Service Areas

Unit values of water use on the miscellany of service areas grouped in this category were derived generally from measured or estimated present deliveries of water to the typical development involved. In most cases the estimates were made in terms of per capita use of water, and the actual acreage of the service area was not a significant factor. In such cases the aggregate amount of water deliveries is relatively very small, and negligible recovery of return flow is involved. For purposes of study, therefore, the estimated unit values of delivery of water to these facilities were considered to be also the measures of consumptive use of applied water.

Both the National Forest and Park Services provided estimates of present and probable ultimate unit deliveries of water to all facilities within their jurisdiction. The estimates were generally in terms of per capita use of water, and were based on actual measurements and experience. They varied widely from place to place and in type of use, and for this reason are not detailed herein.

The total quantity of water used for migratory waterfowl was determined from data furnished by the United States Fish and Wildlife Service, and by those private organizations which operate areas used to feed or attract birds. Unit values of water use were not obtained. The individual operations vary considerably, depending upon the water supply and whether the land is cultivated for crop growth.

For other water service areas not encompassed by the foregoing specific types of water service, unit values of consumptive use of applied water under probable ultimate conditions of development were assigned on a per capita basis. In such areas, sparse residential, industrial, and recreational development

TABLE 139

ESTIMATED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY AND CONSUMPTIVE USE OF WATER ON URBAN AND SUBURBAN AREAS, LAHONTAN AREA

(In feet of depth)

Hydrographic unit		Present		Probable ultimate	
Reference number	Name	Gross delivery	Consumptive use of applied water	Gross delivery	Consumptive use of applied water
1	Surprise Valley	1.0	0.5	2.2	1.1
2	Madeline Plains	0.9	0.5	2.2	1.1
3	Honey Lake	1.2	0.6	2.8	1.4
4	Truckee River	0.4	0.2	0.4	0.2
5	Carson River	1.0	0.5	2.2	1.1
6	Walker River	1.9	1.0	2.2	1.1
7	Mono Lake	1.5	0.8	2.2	1.1
8	Adobe Valley	1.5	0.8	2.2	1.1
9	Owens River	1.9	0.9	2.8	1.4
10	Death Valley	0.6	0.3	3.6	1.8
11	Mojave River	2.3	1.2	3.6	1.8
12	Antelope Valley	2.0	1.0	3.6	1.8

is expected in the future. For areas outside national forests, monuments, and military reservations, it was estimated that the ultimate population density will average about eight persons per square mile, and that per capita consumptive use of water will be about 70 gallons per day. In areas inside national forests, monuments, and military reservations the same per capita use estimates were made, but the population density was assumed to average about four persons per square mile. The period of water use was assumed to be of only three months' duration during the summer for areas above 3,000 feet in elevation, while water service for areas below 3,000 feet in elevation was assumed to be throughout the year.

CONSUMPTIVE USE OF WATER

In general, estimates of the amounts of water consumptively used in the Lahontan Area were derived by applying appropriate unit values of water use to the service areas involved. The estimates represent the seasonal amount of consumptive use of water under mean conditions of water supply and climate. Table 140 presents estimates of present consumptive use of applied water and precipitation in areas having water service, and Table 141 presents corresponding estimates for probable ultimate conditions of development.

FACTORS OF WATER DEMAND

Certain factors relating to water requirements, other than the amount of water consumptively used in a given service area, such as necessary rates, times, and places of delivery, quality, losses, and other pertinent requirements, must be considered in planning water development projects. The most important of these demand factors in the Lahontan Area are those concerned with irrigation development. Those factors related to the water supply for urban, suburban, recreational, and other uses are of secondary importance. The demand factors of principal importance to planning for water resource development of the Lahontan Area are discussed in the following sections.

Monthly Distribution of Water Demands

The demand for irrigation water in the Lahontan Area varies from little or none during the winter months to more than 20 per cent of the seasonal total during dry summer months. Available information indicates that the irrigation water demands in the Truckee and Carson River Basins are heavily concentrated in the late spring and summer months. In the

TABLE 140

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, LAHONTAN AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Other water service areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
1	Surprise Valley	61,600	35,800	200	200	0	62,000
2	Madeline Plains	12,000	7,100	100	negligible	200	12,300
3	Honey Lake	65,400	40,300	200	1,200	7,400	74,200
4	Truckee River	3,200	1,600	negligible	600	300	4,100
5	Carson River	11,000	8,900	100	negligible	0	11,100
6	Walker River	30,300	18,500	100	negligible	100	30,500
7	Mono Lake	2,800	1,900	negligible	negligible	100	2,900
8	Adobe Valley	3,300	1,900	negligible	0	negligible	3,300
9	Owens River	18,200	6,000	100	700	500	19,500
10	Death Valley	25,000	4,100	100	300	4,300	29,700
11	Mojave River	31,400	5,300	100	2,000	500	34,000
12	Antelope Valley	200,000	41,300	400	1,100	700	202,000
	APPROXIMATE TOTALS	464,000	173,000	1,400	6,100	14,100	486,000

TABLE 141

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, LAHONTAN AREA

(In acre-feet)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands: Applied water	Irrigated lands: Precipitation	Farm lots: Applied water	Urban and suburban areas: Applied water	Other water service areas: Applied water	Approximate total consumptive use of applied water
1	Surprise Valley	128,000	78,000	1,000	1,100	100	130,000
2	Madeline Plains	198,000	127,000	1,600	1,600	12,300	214,000
3	Honey Lake	360,000	229,000	2,600	5,200	24,200	392,000
4	Truckee River	31,200	22,300	300	3,700	400	35,600
5	Carson River	15,600	14,600	200	200	600	16,600
6	Walker River	47,600	34,300	400	500	300	48,800
7	Mono Lake	14,700	11,100	200	200	200	15,300
8	Adobe Valley	24,400	18,200	300	300	0	25,000
9	Owens River	205,000	82,000	1,600	3,000	1,100	211,000
10	Death Valley	1,840,000	335,000	10,500	17,200	20,900	1,889,000
11	Mojave River	947,000	169,000	5,200	8,900	3,400	965,000
12	Antelope Valley	1,339,000	353,000	4,300	11,800	1,300	1,356,000
	APPROXIMATE TOTALS	5,151,000	1,473,000	28,200	53,700	64,800	5,298,000

Antelope Valley and Mojave River Hydrographic Units the irrigation demand is more uniform throughout the season, with appreciable use of water even in the winter months. Urban water demands vary from four to six per cent of the annual total during the months of December through March, to over ten per cent from June through September. Representative data on monthly distribution of irrigation and urban water demands in the Lahontan Area are presented in Table 142.

Irrigation Water Service Area Efficiency

In order to determine the irrigation water requirements of the Lahontan Area, it was desirable to estimate the over-all efficiency of irrigation practice in the various service areas. Irrigation water service area efficiency was measured by the ratio of consumptive use of applied irrigation water to the gross amount of irrigation water delivered to a service area. Present irrigation water service area efficiencies were estimated after consideration of geologic conditions of the service areas involved, their topographic position in relation to sources of water supply and to other service areas, consumptive use of water, irrigation practice, and usable return flow. Irrigation practice was determined from records of water diverted in the Surprise Valley, study of present practice in the Carson River Basin, and studies of the Antelope Valley where water not consumptively used returns to ground water storage. Additional factors affecting the estimates of probable ultimate irrigation water service area efficiencies were related to the location and extent of presently undeveloped irrigable lands, as well as the increased cost of developing water. For purposes of illustration, the weighted mean values of all irrigation water service area efficiencies within each hydrographic unit of the Lahontan Area are presented in Table 143.

TABLE 142

DISTRIBUTION OF MONTHLY WATER DEMANDS, LAHONTAN AREA

(In per cent of seasonal total)

Locality and purpose	January	February	March	April	May	June	July	August	September	October	November	December	Total
Irrigation demand													
Truckee River and Carson River Hydrographic Units (Newlands Project, 1909 through 1917)	0	0	2.1	13.6	20.1	18.7	18.9	13.4	9.7	2.7	0.8	0	100.0
Antelope Valley and Mojave River Hydrographic Units[1]	2.0	2.0	5.0	6.0	9.0	12.0	14.0	16.0	13.0	11.0	6.0	4.0	100.0
Urban demand													
Susanville, 1948 through 1952	5.6	4.8	4.5	5.0	7.1	10.0	11.9	15.3	14.1	9.9	6.8	5.0	100.0
Antelope Valley and Mojave River Hydrographic Units[2]	5.0	5.0	6.0	7.0	9.0	11.0	12.0	12.0	11.0	9.0	7.0	6.0	100.0

[1] Based on the average agricultural electric power use.
[2] Based on the average domestic deliveries by water utilities.

TABLE 143

ESTIMATED WEIGHTED MEAN IRRIGATION WATER SERVICE AREA EFFICIENCY WITHIN HYDROGRAPHIC UNITS, LAHONTAN AREA

(In per cent)

Hydrographic unit: Reference number	Hydrographic unit: Name	Present	Probable ultimate
1	Surprise Valley	60	60
2	Madeline Plains	50	50
3	Honey Lake	50	70
4	Truckee River	50	50
5	Carson River	30	50
6	Walker River	50	70
7	Mono Lake	50	50
8	Adobe Valley	50	90
9	Owens River	50	70
10	Death Valley	70	80
11	Mojave River	70	80
12	Antelope Valley	90	90

WATER REQUIREMENTS

Water requirement, as the term is used in this bulletin, refers to the amount of water needed to provide for all beneficial uses of water and for irrecoverable losses incidental to such uses. Water requirements of the Lahontan Area that are primarily nonconsumptive in nature are discussed in general terms in the ensuing section. Following this, water requirements of the area that are consumptive in character are evaluated for both present and probable ultimate conditions of development.

Requirements of a Nonconsumptive Nature

The principal water requirements of a nonconsumptive nature in the Lahontan Area are associated with the preservation and propagation of fish and wildlife, and the generation of hydroelectric power. Other requirements of lesser importance are those for mining, timber, and industry. For the most part, such requirements for water are extremely difficult to evaluate other than in conjunction with definite plans for water resource development. Their consideration in this bulletin, therefore, is limited to discussion of their implications as related to planning for future development of water resources.

Fish and Wildlife. The Lahontan Area, excluding the arid desert region in the southern portion, embodies a large number of excellent trout fishing streams and lakes. The principal game fish is the rainbow trout, which is found in most streams and lakes, but other species of trout also provide considerable angling opportunities. Cutthroat trout are taken primarily in the Walker and Carson Rivers and in Crowley Lake. Eastern brook and brown trout are well distributed, the Truckee and Owens Rivers being the two greatest producers of brown trout. Lake trout (Mackinaw) and kokanee red salmon are found in Lake Tahoe and Donner Lake. Many of the higher lakes and streams, particularly in the southerly Sierra Nevada, contain golden trout. Eagle Lake, in Lassen County, has a unique fishery for the Eagle Lake rainbow trout, as this fish is not found elsewhere. Although the southern and southeastern arid portions of the Lahontan Area contribute very little to the fishery values, some of the streams which flow northward from the San Bernardino Mountains have populations of rainbow trout which offer sport fishing.

Warmwater game fishes, including the black basses, sunfishes, crappies, and catfishes, are present in the Lahontan Area, but the amount of angling for these fishes is light compared to that expended in pursuit of trout. The warmwater game fishes have been stocked in various small reservoirs and farm ponds, and largemouth black bass are also found in the Owens River.

At the request of the Division of Water Resources, a series of estimates was made by the California Department of Fish and Game of the stream flow at certain points required for the protection and maintenance of fish life in each of the important streams of the Lahontan Area. These streams were divided into four classes by the Division, according to the anticipated degree of development for various purposes that would compete with recreational or commercial fishing requirements. These classes are described, and the summer and winter water requirements for fish life, as determined by the Department of Fish and Game, are listed in Appendix F.

The California Department of Fish and Game operates two migratory waterfowl management areas in the Lahontan Area, namely Madeline Plains and Honey Lake. There are also several private gun clubs, which have as their primary purpose the hunting of migratory waterfowl. Many of these areas are also cultivated, and their water requirements are included in the requirements for water on agricultural lands. No satisfactory means were devised for predicting an increase or decrease of private gun clubs, and it was assumed that the water requirements for such use, other than where combined with agricultural use, would be very minor in nature.

Hydroelectric Power. Estimates of the amount of hydroelectric power potentially obtainable from streams in the Lahontan Area under average conditions of complete development, together with the nonconsumptive water requirements for this purpose, are shown in Table 144. The power output was estimated on the assumption that stream runoff will be used primarily for power production. That is, no consideration was given in the estimates to use of the water for other beneficial purposes. It is probable, however, that the streams ultimately will serve a combination of beneficial uses. Accordingly, the actual hydroelectric power output under such combined opera-

TABLE 144

EXISTING AND ESTIMATED POTENTIAL HYDROELECTRIC POWER DEVELOPMENT, LAHONTAN AREA

Stream basin	Average annual power output, in 1,000,000 kilowatt-hours	Installed power capacity, in kilowatts	Average annual water requirement at lowest plant, in 1,000 acre-feet
Truckee River, in California	75	15,000	325
Carson River, in California	120	25,000	200
Walker River, in California	140	30,000	230
Mono Lake Basin	105	25,000	90
Owens River	735	190,000	305
Subtotals	1,175	285,000	1,150
Los Angeles Aqueduct	270	105,000	305*
TOTALS	1,445	390,000	1,150
Existing power plants and plants under construction	931	279,000	

* Owens River water.

tions would be reduced from the estimates presented herein.

The greater part of the runoff of the Lahontan Area occurs in many small, steep streams originating in the high snow fields of the Sierra Nevada at elevations above 10,000 feet, and terminating on the interior plateau at elevations of from 4,000 to 6,000 feet. While the streams are of only limited size, the topography is favorable to many small hydroelectric power developments. The estimated potential installed hydroelectric power capacity of the area is about 390,000 kilowatts, while existing plants and those under construction have an installed capacity of nearly 280,000 kilowatts. Except for the South Coastal Area, where the small amount of hydroelectric power available is now nearly all developed, the Lahontan Area leads the State in the proportion of present development, which is about two-thirds of its estimated potential.

Mining. A small amount of mining is carried on at the present time in the Lahontan Area, and the necessary water for its production is minor in amount. A major portion of the water used for this purpose can be made available for re-use after treatment for removal of acid wastes in order to maintain suitable water quality.

Timber. Commercial timber production in the Lahontan Area is minor in extent, and the water requirements for this purpose are relatively small. Most of the water used in production is available for re-use after being returned to stream channels. This condition is expected to be maintained under probable ultimate conditions.

Requirements of a Consumptive Nature

Estimates of present and probable ultimate water requirements of a consumptive nature within hydrographic units of the Lahontan Area are presented in Table 145. These mean seasonal values represent the amount of water other than precipitation needed to provide for beneficial consumptive use of water on irrigated lands, urban and suburban areas, farm lots, and other water service areas, and for irrecoverable losses of water incidental to these uses. The estimates were derived from consideration of the heretofore presented estimates of consumptive use of applied water, and of water service area efficiencies of hydrographic units.

The water requirements for migratory waterfowl management areas have been estimated by the California Department of Fish and Game and the United

TABLE 145

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER, LAHONTAN AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots		Urban and suburban areas		Other water service areas		Approximate totals	
Reference number	Name	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate
1	Surprise Valley	102,000	214,000	400	2,000	400	2,200	0	100	103,000	218,000
2	Madeline Plains	24,000	397,000	200	3,200	0	3,200	200	12,300	24,400	416,000
3	Honey Lake	131,000	515,000	400	5,200	2,400	10,400	7,400	24,200	141,000	555,000
4	Truckee River	6,300	62,400	0	600	1,200	7,400	300	400	7,800	70,800
5	Carson River	36,700	31,200	200	400	0	400	0	600	36,900	32,600
6	Walker River	60,600	68,000	200	800	0	1,000	100	300	60,900	70,100
7	Mono Lake	5,600	29,400	0	400	0	400	100	200	5,700	30,400
8	Adobe Valley	6,700	27,100	0	600	0	600	0	0	6,700	28,300
9	Owens River	36,500	292,000	200	3,200	1,400	6,000	500	1,100	38,600	302,000
10	Death Valley	35,700	2,300,000	200	21,000	600	34,400	4,300	20,900	40,800	2,376,000
11	Mojave River	44,800	1,183,000	200	10,400	4,000	17,800	500	3,400	49,500	1,215,000
12	Antelope Valley	222,000	1,488,000	800	8,600	2,200	23,600	700	1,300	226,000	1,521,000
	APPROXIMATE TOTALS	712,000	6,607,000	3,000	56,000	12,000	107,000	14,000	65,000	741,000	6,835,000

States Fish and Wildlife Service. Following is a summary of data as of September, 1952, secured from these agencies, concerning present and estimated ultimate water requirements for this use.

	Area inundated, in acres	*Applied water, in acre-feet per season*
Present (1952)	3,500	8,200
Probable ultimate	10,500	46,700

These requirements are included in Table 145 under the heading of "Other Water Service Areas."

Supplemental Requirements

The present supplemental water requirement in each hydrographic unit of the Lahontan Area was taken as equivalent to the estimated deficiency in surface water supply development, plus the estimated ground water overdraft when such was known to exist. The difference between estimated present and probable ultimate water requirements for each hydrographic unit, plus the present supplemental requirement, was taken as the measure of the probable ultimate supplemental water requirement.

In the Lahontan Area the present deficiencies in surface water supply development are of considerable significance to the agricultural economy of the area. In those places, particularly in northerly portions of the area, where the lands are largely irrigated by diversion from streams, late summer and fall stream flows are frequently too small to meet the optimum requirements of crops on developed lands. This enforced undesirable irrigation practice, resulting in most cases from underdevelopment of regulatory storage capacity on the stream systems, adversely affects agricultural crop returns of the area. Therefore, estimates of the amounts of supplemental water necessary in the Lahontan Area to meet the optimum requirements of lands presently irrigated from surface water sources were included in the estimates of supplemental water requirements. Unlike the Lahontan Area, in most of the other major hydrographic areas of the State any present deficiencies in surface water supply development are of relatively minor significance to the general economy of the areas, and, for this reason, were not considered in estimating supplemental water requirements.

Results of prior studies of the use of ground water in the Lahontan Area indicate that an overdraft exists at present only in the Antelope Valley Hydrographic Unit. It is known that the use of ground water in that unit has been intensified substantially since last studied by the Division of Water Resources in 1946, and it is probable that the overdraft has increased proportionately. However, lacking specific knowledge of the amount of such increase in ground water use, the estimates of water supply as developed in 1946 were used in this bulletin.

Table 146 presents the estimates of present and probable ultimate mean seasonal supplemental water requirements of the hydrographic units of the Lahontan Area.

TABLE 146

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS, LAHONTAN AREA

(In acre-feet)

Hydrographic unit		Present	Probable ultimate
Reference number	Name		
1	Surprise Valley	25,000	140,000
2	Madeline Plains	11,000	403,000
3	Honey Lake	60,000	474,000
4	Truckee River	0	63,000
5	Carson River	7,000	2,700
6	Walker River	16,000	25,200
7	Mono Lake	0	24,700
8	Adobe Valley	0	21,600
9	Owens River	0	263,000
10	Death Valley	0	2,335,000
11	Mojave River	0	1,166,000
12	Antelope Valley	160,000	1,455,000
	APPROXIMATE TOTALS	279,000	6,373,000

CHAPTER IX

COLORADO DESERT AREA

The Colorado Desert Area comprises the southeastern portion of California between latitudes 32.5° and 35.5° N., and consists of lands draining directly into the Colorado River and centrally drained desert basins without outlet, such as the basin draining to the Salton Sea. It is bounded on the north by the watershed of the Mojave River, on the south by the international boundary with Mexico, and on the west by the San Bernardino Mountains and the San Jacinto and Peninsular Ranges. The Colorado River and the Nevada state line bound the area on the east. The area is designated Area 7 on Plate 8, and includes all of Imperial County as well as portions of San Diego, Riverside, and San Bernardino Counties. The Colorado Desert Area encompasses a range in elevation from about 235 feet below sea level at Salton Sea to over 11,400 feet above sea level in the San Bernardino Mountains. Among the principal incorporated cities are Banning, Palm Springs, Indio, Brawley, El Centro, Blythe, and Needles.

The lands of the Colorado Desert Area having rights in and to the waters of the Colorado River were excluded from the presentations in this chapter dealing with conditions of probable ultimate development. Under their established rights these lands have a large imported water supply available, sufficient in quantity to meet their requirements under conditions of probable ultimate development. In general, the lands are highly developed to irrigated agriculture at the present time, and plans have been made for their complete development. In most instances the existing canals and appurtenant water supply works have been constructed with sufficient capacity to serve water to meet the ultimate needs of the lands. Since one of the principal purposes of this bulletin is to determine the ultimate supplemental water requirements which will have to be provided for under The California Water Plan, the lands of the Colorado Desert Area which are already completely planned for were excluded from consideration in this respect. The boundaries of the lands in the Colorado Desert Area having rights in and to the waters of the Colorado River are shown on sheets 25 and 26 of Plate 9.

In order to facilitate the present studies, the Colorado Desert Area was divided into six hydrographic units, the boundaries of which lie on the watershed divides of the principal streams or enclose a geographically similar area, as shown on Plate 8. Table 147 presents the six hydrographic units and their areas, as well as the area having rights in and to the waters of the Colorado River. Table 148 similarly presents the areas of the portion of each county included within the Colorado Desert Area.

TABLE 147

AREAS OF HYDROGRAPHIC UNITS, COLORADO DESERT AREA

Hydrographic unit: Reference number	Hydrographic unit: Name	Acres
1	Twentynine Palms	3,867,000
2	Coachella Valley	1,087,000
3	Salton Sea	1,898,000
4	Imperial Valley	113,000
5	Colorado River	2,095,000
6	Lanfair Valley	2,035,000
	APPROXIMATE SUBTOTAL	11,100,000
	Areas having rights in and to the waters of the Colorado River	1,321,000
	APPROXIMATE TOTAL	12,420,000

TABLE 148

AREAS OF COUNTIES WITHIN BOUNDARIES OF COLORADO DESERT AREA

County	Acres
Imperial	1,658,000
Riverside	3,138,000
San Bernardino	5,494,000
San Diego	805,000
Approximate subtotal	11,100,000
Areas having rights in and to the waters of the Colorado River	1,321,000
APPROXIMATE TOTAL	12,420,000

The arid climate of the Colorado Desert Area is characterized by short, mild winters and exceptionally hot, dry summers. The greatest rainfall in the area is in the higher elevations of the Peninsular Range and the San Bernardino Mountains. The mean seasonal depth of precipitation at Raywood Flats in the San Bernardino Mountains is 37.8 inches, part of which may occur in the form of snow. Seasonal precipitation in the valley areas averages 3.6 inches in depth at Indio, 3.2 inches at El Centro, 4.0 inches at Blythe, and 4.8 inches at Needles. The greater portion of the rainfall in the valley areas is from localized thunder storms, resulting in extreme variability in

Date Gardens Near Indio

Courtesy Spence Air Photos

Coachella Branch of All-Amerian Canal

Courtesy State Division of Highways

distribution of precipitation. At several stations within the area no precipitation has been recorded for entire seasons. The rainfall on valley and mesa lands is generally so minor in amount that it has little practical significance to the water resources of the area.

The estimated mean seasonal natural runoff of streams in the Colorado Desert Area is about 221,000 acre-feet, or about 0.3 per cent of that for the entire State. For purposes of this bulletin the flow in the Colorado River was not included in this estimate. Somewhat less than one-half of the runoff occurs in the centrally drained basins. This runoff is not ordinarily available for surface diversion due to variability in time and amount of its occurrence. The estimated mean seasonal natural runoff of the Whitewater River and its tributaries is approximately 61,800 acre-feet, or about 28 per cent of the total runoff of the area, and forms an important part of the water supply of the Coachella Valley. A few streams that originate in the higher elevations of the Peninsular Range flow perennially in portions of their headwater channels, but the flow quickly seeps and evaporates upon reaching the valley floor. During the occasional periods of extreme rainfall, surface stream flow reaches the Salton Sea. Torrential floods of short duration, caused by the characteristic cloudburst type of rainfall distribution, may occur at any place within the area. The Salton Sea, about 345 square miles in area at an elevation of 235 feet below sea level, has a present mineral content slightly greater than that of sea water, precluding its use for domestic or irrigation purposes.

As shown in Plate 4, a total of 45 valley fill areas, which may or may not contain usable ground water, has been identified in the Colorado Desert Area. Only two basins, underlying Coachella and Borrego Valleys, are appreciably developed for water supply purposes. Ground water is pumped from these two basins and used for domestic and irrigation purposes in the valleys. Little information is available concerning most of the other 43 valley fill areas, as they have not been subject to extensive development.

Population in the Colorado Desert Area, with the exception of urban and recreational areas in the Coachella Valley, has not kept pace with the large over-all growth which has occurred in other portions of the State. Urban developments are for the most part adjuncts to the agricultural activity, which has not changed greatly in areal extent in the decade from 1940 to 1950. Population in the several desert resort areas more than doubled in the 1940-1950 period. Table 149 presents the data on population in eight of the principal urban communities from 1940 to 1950. It should be noted that population in resort areas such as Palm Springs, Desert Hot Springs, and Twentynine Palms is subject to seasonal variation.

The economy of the Colorado Desert Area is based upon agricultural development in the Imperial, Coachella, and Palo Verde Valleys, and the Yuma Project. The mild winter climate and consequently practically year-round growing season, combined with ground water development in localized areas and importation of Colorado River water for irrigation, have permitted the expansion of specialty produce, such as off-season truck crops, citrus, dates, cotton, and table grapes.

TABLE 149

POPULATION OF PRINCIPAL URBAN CENTERS, COLORADO DESERT AREA

City	1940			1950		
	Within city limits	In suburbs	Total	Within city limits	In suburbs	Total
El Centro	10,000	1,000	11,000	12,600	3,000	15,600
Brawley	11,700	700	12,400	11,900	1,500	13,400
Banning	3,900	0	3,900	7,000	2,100	9,100
Indio	2,300	1,200	3,500	5,300	2,700	8,000
Palm Springs	3,400	0	3,400	7,700	0	7,700
Calexico	5,400	600	6,000	6,400	0	6,400
Blythe	2,400	600	3,000	4,100	1,800	5,900
Needles	3,600	0	3,600	4,100	0	4,100

Irrigation in the Imperial Valley was first conceived about 1860, but did not commence until the last decade of the 19th century. The Colorado River Irrigation Company was formed in 1892, and surveys and plans were made to divert water from the Colorado River north of the international boundary, and convey it to the Alamo River by a canal through Mexico. The water would flow through the Alamo River channel to the Imperial Valley, where distribution of the imported supply would be made. The original company failed to secure adequate financing, and the California Development Company was formed in 1896, with its subsidiary, La Sociedad de Riego y Terrenos de la Baja California, S. A., formed in 1898. Construction of works by these companies between 1900 and 1902 made possible the delivery of water to Mexico and to the Imperial Valley in 1901. Difficulties were encountered in maintaining an adequate flow of water in the canal and river channel, and the companies petitioned the Mexican Government for permission to divert 10,000 second-feet below the international boundary. Under authority of the Mexican Government, two dredger cuts were made in the banks of the Colorado River below the international boundary in 1905. Control gates were not installed at the cuts, as they had not then been approved by the Mexican Government. In the winter of 1905 the Colorado River reached an unprecedented stage and breached the lower dredge cut, the uncontrolled flow reaching the Salton Sea through the New and Alamo Rivers, which were eroded to their present depths at that time. Closure of the break and confinement of the Colorado River to its channel required six attempts and three years to complete. Legal difficulties

Courtesy Blythe Photo Shop

Diversion From Colorado River for Palo Verde Irrigation District beset the California Development Company, and judgments for damages resulting from the flow of Colorado River water through the dredge cut were incurred, forcing receivership of the company in 1909. The company operated under a receivership from 1909 until 1916, during which time major development of the Imperial Valley occurred. The Imperial Irrigation District, which in 1950 comprised almost 894,000 acres in the Imperial Valley, was formed in 1911, and in 1916 purchased the irrigation system, including the properties of the California Development Company and its subsidiary, the Compania de Terrenos y Aguas de la Baja California, S. A. Imported water supplies were delivered to Imperial Valley through the Mexican canal system until 1942, when the All-American Canal, heading at Imperial Dam on the Colorado River, commenced operation. The Imperial Irrigation District assumed operation of the All-American Canal system on May 1, 1952.

The Main All-American Canal, constructed by the United States Bureau of Reclamation, has a capacity of 10,000 second-feet at the point above Drop 1 where the canal divides into two branches. The branch to the Coachella Valley has an initial capacity of 2,500 second-feet at the turnout, which is gradually reduced to 1,500 second-feet at the northern end of the East Mesa area of the Imperial Irrigation District. The Imperial Irrigation District has capacity to receive water at the rate of 7,500 second-feet through the continuation of the Main Branch of the All-American Canal. This branch supplies all of the district with the exception of that portion of the East Mesa supplied by the Coachella Branch.

The Coachella Valley, comprising the northern portion of the Salton Basin, has developed for the most part since 1900. Prior to 1900, the Southern Pacific Company received alternate sections of the public lands in consideration for the construction of a railroad through the valley, completed in 1879. Remaining lands, other than Indian reservations, were acquired in 1885 and 1886 by private parties, under the provisions of the Desert Land Act. In 1894 the Southern Pacific Company drilled a deep well at Mecca, developing an abundant supply of good quality artesian water. This discovery stimulated interest in agricultural development, but the excessive cost of the then available methods of well drilling forestalled extensive development until 1900, at which time improved methods of drilling became economical. Wells were drilled throughout the southern portion of the valley, and by 1907 over 400 wells existed between Indio and the Salton Sea, of which about 300 were artesian. Early farms were located close to the Salton Sea, but many of these have since been abandoned due to salinity resulting from poor drainage in the fine-textured soils in the lower portion of the Coachella Valley. The northward movement of agriculture away from the artesian area was made possible by improvement of pumping equipment.

Agricultural development in the Coachella Valley was limited by an insufficient local water supply for full development of irrigable lands. In 1918 the Coachella Valley County Water District was organized to protect the existing water supply development and to secure an imported supplemental water supply from the Colorado River. The district assumed control of the Coachella Valley Storm Water District in 1937. The Coachella Valley County Water District now includes about 268,000 acres, of which about 136,000 acres are within the service area of the All-American Canal. In 1934, the district entered into a contract with the United States Bureau of Reclamation for the construction of facilities for importation of Colorado River water to Coachella Valley, resulting in the construction of the Coachella Branch of the All-American Canal. The canal conveys Colorado River water along the east side of Coachella Valley, crosses the valley just north of the City of Indio, and turns southerly along the west side of the valley. Flood detention basins have been built on the upstream side of the canal in order to protect the canal and to provide flood protection for developed lands. Delivery of water to most of the developed lands is accomplished by an underground distribution system.

Water rights for lands in Palo Verde Valley, lying along the right bank of the Colorado River in the vicinity of Blythe, date from 1877 when Thomas H. Blythe filed for the water necessary for the irrigation of 40,000 acres. Little development occurred until 1904, when the water rights were transferred to the Palo Verde Land and Water Company. The rights were subsequently assigned to the Palo Verde Mutual Water Company in 1908. The agricultural development of the valley was given impetus by the completion of the first railroad connection in 1915. The present water service agency is the Palo Verde Irrigation District, which included about 104,000 acres within its boundaries in 1950. The irrigation water distribution system was purchased by the district in 1923. The original headgate works for gravity diversion of Colorado River water to the canal system were located near the northeast corner of the valley. The regimen of the Colorado River was changed after Parker Dam and Headgate Rock Dam were constructed, and in 1945 the construction of a temporary rock weir across the Colorado River immediately upstream from the old headgate works was necessary. The diversion canal was extended to a point upstream from the rock weir to permit continued gravity diversion of irrigation supplies.

The Yuma Project, a United States Bureau of Reclamation irrigation development, was authorized in 1904, and is located in California and Arizona on both sides of the Colorado River. The California portion of the project, the Reservation Division, consists of the Bard and Indian Units. The portion of the project in California, previously served by a canal from Laguna Dam, is now served by the All-American Canal. It embraces about 15,000 acres, 8,000 of which are allotted to Indians. The remaining 7,000 acres, which constitute the Bard Irrigation District, are allotted to non-Indian operators.

The Colorado Desert Area has taken its place in recent years as one of the nation's outstanding resort areas. Resorts are principally located in and adjacent to Palm Springs, Desert Hot Springs, and Twentynine Palms. The development of "dude ranch" resorts and other desert types of recreational facilities has attracted thousands of seasonal visitors. While the principal resort season occurs during the winter months, there is an appreciable year-round influx of tourists and visitors to the area.

Iron ore production in California was relatively small until 1942, when heavy demands were placed on the State's iron deposits by the Kaiser Steel Company blast furnaces and steel plant at Fontana. This plant secures its ore from the Eagle Mountains deposit located about 40 miles east of Indio, the only current California source of ore for pig iron. Scattered mining operations in the Colorado Desert Area also produce gold, silver, manganese, lead, pumice, copper, gypsum, and sand and gravel.

The two military establishments of present importance to the economy of the Colorado Desert Area are the El Centro Naval Air Station and the Salton Sea Experimental Station.

In summary, it should be emphasized that water is employed in the Colorado Desert Area primarily for the production of agricultural crops, and to a much smaller extent for mining and for municipal purposes including domestic and industrial. Insofar as is known, no water is now utilized in the area for the generation of hydroelectric power, except as a by-product of water diverted through the All-American Canal, nor for navigation excepting to a very minor extent for recreation on the lower Colorado River, nor is it foreseen that there will ever be appreciable requirements of such nature. Flood control structures have been constructed on the Whitewater River north of the Salton Sea. A system of levees extending through both Mexico and California was constructed early in the 20th century to prevent a recurrence of the break-through of the Colorado River to the Salton Sea. The construction of Hoover Dam in 1935 greatly reduced the threat of floods on the lower Colorado River. The present consumptive use of water for recreation is limited to water consumed for domestic purposes in resort and recreational areas.

There follows in this chapter a presentation of available data and estimates pertinent to the nature and extent of water utilization and requirement in the Colorado Desert Area, both at the present time and under probable conditions of ultimate development. The presentation does not include data and estimates for the ultimate service areas in the Palo Verde Irrigation District, the Yuma Project, and the All-American Canal Project. These projects are covered, and their aggregate service area determined, by the Boulder Canyon Project Act and related documents, including appropriative water rights and contracts between the operating agencies and the Secretary of the Interior for delivery of water to meet their supplemental requirements from the Colorado River. In view of these facts and for the purpose of this bulletin, the named areas constitute a special entity whose water supply and requirements need not be considered in detail in connection with The California Water Plan. Consideration of those areas in this bulletin was limited to present conditions. The data and estimates for ultimate conditions presented in this chapter apply only to those parts of the Colorado Desert Area outside the Boulder Canyon Project service area.

PRESENT WATER SERVICE AREAS

As a necessary step in estimating the amount of the water requirement in the Colorado Desert Area, with the present pattern of land use and under mean conditions of water supply and climate, determinations were made of the location, nature, and extent of presently irrigated and urban and suburban water service areas. Remaining lands were not classified in detail with regard to their relatively minor miscellaneous types of water service, although such water service was given consideration in estimating the present water requirement.

Irrigated Lands

It was determined that under present conditions of development in the Colorado Desert Area, about 565,000 acres are irrigated in a given year, on the average. This constitutes approximately eight per cent of the land irrigated throughout California.

Irrigated grain and hay, alfalfa, and truck crops are dominant in acreage in the Colorado Desert Area. In the Coachella Valley the principal crops are dates, early grapes, citrus, and winter truck crops such as tomatoes, corn, squash, and string beans. Approximately 90 per cent of all domestic dates marketed in the United States are grown here. The largest acreages of irrigated crops in the agricultural areas along the Colorado River and in the Imperial Valley are alfalfa, cotton, flax, sugar beets, truck, and grain. The principal winter truck crops in the Imperial Valley are lettuce, carrots, tomatoes, peas, and melons.

Cropping practices in the Colorado Desert Area are somewhat different than in other areas of the State in that the growing seasons are long, temperatures are extremely high in midsummer, and all water used in crop production is provided through irrigation. Much of the land will produce three truck crops in two years, or produce one crop of truck and one of cotton or sugar beets in the same year. Interplanting of dates and citrus is common practice. Alfalfa land in the Imperial Valley commonly yields six cuttings per year, even though the crop is held dormant during a portion of the summer months.

The field surveys upon which determinations of irrigated acreage in the Colorado Desert Area were based were accomplished during the period from 1948 through 1951, by several agencies with varying standards and degrees of accuracy. Information regarding the dates of field mapping and sources of data is contained in Appendix D. Based on the available survey data, the irrigated lands were classified into various crop groups, with a view to segregating those of similar water use. As a result of the double-cropping that prevails in the area and the longer growing seasons, the area of each crop produced annually is necessarily approximate. A list of the various crop groups into which irrigated lands of the Colorado Desert Area were classified follows:

Alfalfa	Hay, seed, and pasture
Pasture	Grasses and legumes, other than alfalfa, used for livestock forage
Orchard	Deciduous fruit and nuts
Citrus	Oranges, lemons, grapefruit, and tangerines
Dates	
Vineyard	Principally Thompson seedless grapes
Truck crops	Intensively cultivated fresh vegetables, including lettuce, carrots, tomatoes, peas, beans, onions, squash, melons, and sweet corn
Cotton	
Sugar beets	
Hay and grain	Barley, wheat, and oats
Miscellaneous field crops	Milo, sesbania, hemp, flax, safflower, corn, and beans.

It is estimated that approximately 8,000 acres in the Colorado Desert Area are occupied by farm lots at the present time. These consist of farm buildings and the immediately adjacent yards and gardens receiving water service.

Summaries of presently irrigated acreages within the Colorado Desert Area, by the various crop groups, are presented in Tables 150 and 151. Table 150 lists the acreages by hydrographic units, and Table 151 by counties.

Urban and Suburban Water Service Areas

It was determined that under present conditions of development in the Colorado Desert Area approximately 14,000 acres are devoted to urban and suburban types of land use. For the most part, the business, commercial, and industrial establishments and surrounding homes included in this areal classification receive a municipal type of water supply, although some industries and many of the suburban homes have individual pump and pressure water supply systems. Areas of urban and suburban water service within each hydrographic unit of the Colorado Desert Area are listed in Table 152, and within each county in Table 153. It should be noted that areas shown are gross acreages, as they include streets and intermingled undeveloped lands that are a part of the urban type of community.

Unclassified Areas

Remaining lands in the Colorado Desert Area, other than those that are irrigated or urban and suburban in character, were not classified in detail as regards present water service. Less than 10,000 acres of a total of about 12,300,000 acres of such remaining lands actually receive water service at the present

TABLE 150

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, COLORADO DESERT AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Orchard	Citrus	Dates	Vineyard	Truck crops	Sugar beets	Cotton	Hay and grain	Miscellaneous field crops	Net irrigated area	Farm lots	Included nonwater service areas	Approximate gross area
1	Twentynine Palms	1,600	400	0	0	0	0	0	0	0	0	0	2,000	negligible	negligible	2,000
2	Coachella Valley	2,400	1,500	1,400	2,500	5,700	7,100	4,100	0	4,400	400	700	30,200	700	900	31,800
3	Salton Sea	500	100	0	0	100	1,400	100	0	0	0	300	2,500	100	100	2,700
4	Imperial Valley	168,000	2,700	100	1,900	200	1,500	63,700	34,100	27,900	89,000	77,900	467,000	4,500	11,400	483,000
5	Colorado River	30,800	3,500	0	100	100	0	10,100	0	1,700	10,900	6,500	63,700	2,600	1,500	67,800
6	Lanfair Valley	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
	APPROXIMATE TOTALS	203,000	8,200	1,500	4,500	6,100	10,000	78,000	34,100	34,000	100,000	85,400	565,000	7,900	13,900	587,000

TABLE 151

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN COUNTIES, COLORADO DESERT AREA

(In acres)

County	Alfalfa	Pasture	Orchard	Citrus	Dates	Vine-yard	Truck crops	Sugar beets	Cotton	Hay and grain	Miscel-laneous field crops	Net irrigated area	Farm lots	Included nonwater service areas	Approxi-mate gross area
Imperial	169,000	3,500	100	2,000	300	1,500	64,400	34,100	27,900	90,500	82,300	476,000	4,700	11,600	492,000
Riverside	32,200	4,200	1,400	2,500	5,700	7,100	13,500	0	6,100	9,800	2,800	85,300	3,100	2,200	90,600
San Bernardino	1,600	400	0	0	0	0	0	0	0	0	0	2,000	negligible	negligible	2,000
San Diego	500	100	0	0	100	1,400	100	0	0	0	300	2,500	100	100	2,700
APPROXIMATE TOTALS	203,000	8,200	1,500	4,500	6,100	10,000	78,000	34,100	34,000	100,000	85,400	565,000	7,900	13,900	587,000

time. These relatively minor service areas consist of scattered developed portions of national forests and monuments, public parks, private recreational areas, and military reservations.

The San Bernardino and Cleveland National Forests extend into the Colorado Desert Area, and aggregate 240,000 acres within the area boundaries. These national forests are in the higher elevations of the San Bernardino Mountains and the Peninsular Range. Approximately 500 acres of the national forest lands are presently irrigated, which acreage is included in the values listed in Tables 150 and 151. Within the national forests there are public camps, trailer parks, and other accommodations for tourists, but the actual water service area involved in these features is small. Joshua Tree National Monument, under jurisdiction of the National Park Service, includes some 687,000 acres of desert land, but only a few developed areas adjacent to wells and springs require water service.

The Division of Beaches and Parks of the California Department of Natural Resources at present administers three state parks in the Colorado Desert Area. Salton Sea, Anza Desert, and Borrego State Parks aggregate approximately 460,000 acres, but water service primarily consists of domestic supplies for the permanent buildings and surrounding grounds, and water supplies for camp grounds and picnic areas. The area of land under control of the military authorities within the Colorado Desert Area is quite extensive. However, the water requirements are minor, for the land is utilized for training and experimental purposes.

Summary

Table 152 comprises a summary of present water service areas within hydrographic units of the Colorado Desert Area. A similar summary for counties of the area is presented in Table 153.

TABLE 152

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC UNITS, COLORADO DESERT AREA

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Irrigated lands	Urban and suburban areas	Approximate total
1	Twentynine Palms	2,000	800	2,800
2	Coachella Valley	31,800	4,200	36,000
3	Salton Sea	2,700	200	2,900
4	Imperial Valley	483,000	7,700	491,000
5	Colorado River	67,800	1,300	69,100
6	Lanfair Valley	0	0	0
	Subtotals	587,000	14,200	601,000
	Unclassified areas receiving water service			10,000
	APPROXIMATE TOTAL			611,000

TABLE 153

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN COUNTIES, COLORADO DESERT AREA

(In acres)

County	Irrigated lands	Urban and suburban areas	Approximate total
Imperial	492,000	7,700	500,000
Riverside	90,600	4,800	95,400
San Bernardino	2,000	1,500	3,500
San Diego	2,700	200	2,900
Subtotals	587,000	14,200	601,000
Unclassified areas receiving water service			10,000
APPROXIMATE TOTAL			611,000

PROBABLE ULTIMATE WATER SERVICE AREAS

To aid in estimating the amount of water that ultimately will be utilized in the Colorado Desert Area outside the prescribed service area of the Colorado River, projections were made to determine the probable ultimate irrigated and urban and suburban water service areas. It was assumed that the remaining lands, for convenience referred to as "other water service areas," ultimately will be served with water commensurate with their needs.

Irrigated Lands

A reconnaissance land classification survey was made of the Colorado Desert Area during the period from January to April, 1950, by the State Division of Water Resources. For lands covered by this field survey the irrigable areas were delineated on the best available base maps, the Metropolitan Water District of Southern California topographic sheets with a scale of 1 : 120,000. Criteria utilized in segregating the irrigable lands were identical with those utilized throughout the State. Limiting factors in the area were, in most cases, those relating to the available moisture-holding capacities and inherent fertility, topography, and degree of rockiness of the soils. Soil samples were taken from 95 representative locations throughout the area, and moisture retention studies were made by the Soil Conservation Service, United States Department of Agriculture, in its laboratory at Pomona.

Based on data from the land classification survey, excluding lands having rights in and to the waters of the Colorado River, it was estimated that a gross area of approximately 552,000 acres in the Colorado Desert Area is suitable for irrigated agriculture. With the exception of farm lots and certain lands within the gross irrigable area that experience indicates will never be served with water, such as lands occupied by roads, railroads, etc., it was estimated that under ultimate conditions of development a net area of approximately 475,000 acres will actually be irrigated. Table 154 presents these estimates for hydrographic units of the Colorado Desert Area, and Table 155 for the various counties.

TABLE 154

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC UNITS, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
1	Twentynine Palms	166,000	3,700	21,300	141,000
2	Coachella Valley	43,700	700	5,400	37,600
3	Salton Sea	86,500	1,300	9,900	75,300
4	Imperial Valley	12,500	200	1,300	11,000
5	Colorado River	28,600	500	3,200	24,900
6	Lanfair Valley	215,000	3,700	26,000	185,000
	APPROXIMATE TOTALS	552,000	10,100	67,100	475,000

TABLE 155

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN COUNTIES, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acres)

County	Gross irrigable area	Farm lots	Included nonwater service area	Approximate net irrigated area
Imperial	14,300	200	1,600	12,500
Riverside	68,900	1,100	8,100	59,700
San Bernardino	390,000	7,600	48,400	334,000
San Diego	78,800	1,200	9,000	68,600
APPROXIMATE TOTALS	552,000	10,100	67,100	475,000

The probable ultimate crop pattern for irrigated lands of the Colorado Desert Area, excluding lands having rights in and to the waters of the Colorado River, is presented in Table 156. The crop grouping parallels that used in the case of present development, except that grain and sugar beets are included with field crops.

As early as 1908, an organization planned development of an area in excess of 130,000 acres in Chuckawalla Valley. Congress passed an act authorizing a diversion dam in the Colorado River for this development, and an application was made to the State for a water right. Efforts to secure private financing were unsuccessful at the time, and the project was finally abandoned due to the limitation placed on California's use of Colorado River water. Most of these lands were not included in the irrigable areas in this bulletin.

Urban and Suburban Water Service Areas

While it is expected that urban and suburban growth in the Colorado Desert Area generally will be associated with further development of agriculture, favorable climate and scenic attractions will probably influence growth of certain population centers. It was estimated that under ultimate conditions of development urban and suburban water service areas will be approximately 14,000 acres, excluding lands having rights in and to the waters of the Colorado River. Urban and suburban types of land use are expected to occupy the same localities as at present for the most part, but vacant lands will be filled and densities increased. In the case of irrigable lands not now served with water, it was assumed that new urban centers would develop as water supplies are made available. The locations and boundaries of urban communities were not delineated, but an estimate was made of the probable area devoted to this use. In addition, it is probable that urban encroachment will occur on surrounding irrigable lands to some extent. No attempt was made to delineate the boundaries of

TABLE 156

PROBABLE ULTIMATE PATTERN OF IRRIGATED CROPS, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acres)

Hydrographic unit: Reference number	Hydrographic unit: Name	Alfalfa	Pasture	Orchard	Citrus	Dates	Vineyard	Truck crops	Sugar beets	Cotton	Hay and grain	Miscellaneous field crops	Approximate total
1	Twentynine Palms	75,500	3,200	4,900	0	0	20,000	22,000	0	0	5,000	10,000	141,000
2	Coachella Valley	3,000	2,400	5,000	3,800	2,500	7,000	7,500	500	1,600	4,200	100	37,600
3	Salton Sea	5,000	1,000	4,500	500	0	10,000	5,000	300	0	49,000	0	75,300
4	Imperial Valley	1,800	400	0	1,700	0	2,400	1,900	0	2,000	700	100	11,000
5	Colorado River	7,500	100	0	4,500	0	1,500	3,500	0	0	6,500	1,300	24,900
6	Lanfair Valley	88,000	7,500	0	0	0	0	28,500	0	0	29,600	31,500	185,000
	APPROXIMATE TOTALS	181,000	14,600	14,400	10,500	2,500	40,900	68,400	800	3,600	95,000	43,000	475,000

TABLE 157

OTHER WATER SERVICE AREAS UNDER PROBABLE ULTIMATE CONDITIONS, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acres)

Hydrographic unit		Inside national forests, monuments, and military reservations		Outside national forests, monuments, and military reservations		Approximate total
Reference number	Name	Above 3,000-foot elevation	Below 3,000-foot elevation	Above 3,000-foot elevation	Below 3,000-foot elevation	
1	Twentynine Palms	306,000	319,000	677,000	2,396,000	3,698,000
2	Coachella Valley	248,000	48,600	182,000	558,000	1,037,000
3	Salton Sea	5,500	0	313,000	1,493,000	1,811,000
4	Imperial Valley	0	0	0	101,000	101,000
5	Colorado River	0	0	12,200	2,053,000	2,065,000
6	Lanfair Valley	0	0	419,000	1,399,000	1,818,000
	APPROXIMATE TOTALS	559,000	368,000	1,603,000	8,000,000	10,530,000

such encroachment for the purposes of the present studies, nor to determine what portion will be on irrigable lands. The estimate of probable ultimate urban and suburban water service areas is included in Table 158, and the areas shown are gross acreages, including streets, vacancies, etc.

Other Water Service Areas

Remaining lands of the Colorado Desert Area, not classified as irrigable or urban and suburban under conditions of ultimate development, aggregate about 10,530,000 acres, or 95 per cent of the area. This does not consider lands having rights in and to the waters of the Colorado River. As previously mentioned, it was assumed that ultimately these other water service areas will be served with water in amounts sufficient for their needs. No attempt was made to segregate these "other water service areas" in detail in regard to the nature of their probable ultimate water service. However, as shown in Table 157, they were broken down for convenience in estimating water requirements into those portions inside and outside of national forests, monuments, and military reservations, and above and below an elevation of 3,000 feet. The lands classified as "other water service areas" include recreational developments both public and private, military establishments, residential and industrial types of land use outside of urban communities, etc. By far the greater portion of the lands are situated below 3,000 feet in elevation, and are characterized by rough topography interspersed with undrained, alluvial-filled basins. It is expected that even under conditions of ultimate development much of this large area will be sparsely settled, and will have very minor requirements for water service.

Summary

Table 158 comprises a summary of probable ultimate water service areas, segregated into irrigable, urban and suburban areas, and other water service areas, and excluding lands having rights in and to the waters of the Colorado River.

TABLE 158

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acres)

Hydrographic unit		Irrigable lands	Urban and suburban areas	Other water service areas	Approximate total
Reference number	Name				
1	Twentynine Palms	166,000	2,800	3,698,000	3,867,000
2	Coachella Valley	43,700	6,400	1,037,000	1,087,000
3	Salton Sea	86,500	800	1,811,000	1,898,000
4	Imperial Valley	12,500	0	101,000	113,000
5	Colorado River	28,600	1,700	2,065,000	2,095,000
6	Lanfair Valley	215,000	2,000	1,818,000	2,035,000
	APPROXIMATE TOTALS	552,000	13,700	10,530,000	11,100,000

UNIT VALUES OF WATER USE

Unit values of water use were determined in accordance with methods as set forth in Chapter II, "Methods and Procedures." Available data from recent investigations in the Colorado Desert Area were utilized whenever possible in order to refine estimates derived or computed from climatological data.

Irrigation Water Use

Estimates of unit values of water use in the Coachella Valley, Salton Sea, Imperial Valley, and Colorado River Hydrographic Units of the Colorado Desert Area were based on data resulting from actual soil moisture depletion studies conducted in the Coachella Valley, and upon a study of inflow to and outflow of water from the Imperial Valley during a recent period. Unit values of water use for Lanfair

Valley were assumed to be the same as estimated for hydrographic units on the lower Mojave River in the Lahontan Area. As set forth in the discussion of land use, it is the practice in some localities to raise two or three crops on the same land in a given season. The resulting increased use of water was considered in estimating average unit values of water use for truck crops. Unit mean seasonal consumptive use of applied water on farm lots was estimated to be about 0.5 foot in depth, and of precipitation about 0.3 foot of depth. These estimates were employed for both present and probable ultimate conditions of development.

Climatic factors affecting consumptive use of water were not sufficiently variable to justify the use of different unit values of water use in each hydrographic unit. Table 159 presents the estimated unit values of mean seasonal consumptive use of applied irrigation water and of precipitation on lands devoted to crops of the various groups.

TABLE 159

ESTIMATED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF WATER ON IRRIGATED LANDS, COLORADO DESERT AREA

(In feet of depth)

Crop	Hydrographic units					
	Coachella Valley, Salton Sea, Imperial Valley, and Colorado River			Twentynine Palms and Lanfair Valley		
	Applied water	Precipitation	Total	Applied water	Precipitation	Total
Alfalfa	4.2	0.3	4.5	2.9	0.3	3.2
Pasture	5.0	0.3	5.3	2.7	0.3	3.0
Orchard	2.3	0.3	2.6	2.2	0.3	2.5
Citrus	4.0	0.3	4.3	---	---	---
Dates	6.0	0.3	6.3	---	---	---
Vineyard	3.6	0.3	3.9	2.4	0.3	2.7
Truck crops	3.0	0.3	3.3	1.5	0.3	1.8
Sugar beets	2.5	0.3	2.8	---	---	---
Cotton	3.0	0.3	3.3	---	---	---
Rice	5.0	0.3	5.3	---	---	---
Hay and grain	1.8	0.3	2.1	1.0	0.3	1.3
Miscellaneous field crops	2.4	0.3	2.7	1.6	0.3	1.9

Urban and Suburban Water Service Areas

Present unit seasonal values of use of water on urban and suburban water service areas of the Colorado Desert Area were estimated largely on the basis of available records of delivery of water to the areas, as compiled by municipalities and other public water service agencies. Probable ultimate values of water deliveries were estimated by applying to the present values derived percentage factors to account for expected future increase in population densities and in per capita water use. Table 160 presents the estimates of present and probable ultimate unit seasonal values of gross water deliveries to and consumptive use of water on urban and suburban water service areas.

TABLE 160

ESTIMATED MEAN SEASONAL UNIT VALUES OF WATER DELIVERY IN URBAN AND SUBURBAN AREAS, COLORADO DESERT AREA

(In feet of depth)

Hydrographic unit		Gross delivery*	
Reference number	Name	Present	Probable ultimate
1	Twentynine Palms	1.2	2.5
2	Coachella Valley	1.7	3.4
3	Salton Sea	1.6	3.2
4	Imperial Valley	1.7	3.7
5	Colorado River	1.5	2.5
6	Lanfair Valley	0	2.2

* Assumed equivalent to consumptive use of applied water.

Other Water Service Areas

Unit values of water use on the miscellany of service areas grouped in this category were derived generally from measured or estimated present deliveries of water to the typical development involved. In most cases the estimates were made in terms of per capita use of water, and the actual acreage of the service area was not a significant factor. In such cases the aggregate amount of water deliveries is relatively very small, and negligible recovery of return flow is involved. For purposes of study, therefore, the estimated unit values of delivery of water to these facilities were considered to be also the measures of consumptive use of applied water.

Both the National Forest and Park Services provided estimates of present and probable ultimate unit deliveries of water to all facilities within their jurisdiction. The estimates were generally in terms of per capita use of water, and were based on actual measurements and experience. They varied widely from place to place and in type of use, and for this reason are not detailed herein.

The value of unit use of water by military establishments was derived on a per capita basis, from available records of delivery of water and estimates of population of the areas involved. Present consumptive use of applied water on these military bases is estimated to average about 75 gallons per capita per day. It was assumed that this value will hold in the future.

For other water service areas not encompassed by the foregoing specific types of water service, unit values of consumptive use of applied water under probable ultimate conditions of development were assigned on a per capita basis. In such areas, a sparse residential, industrial, and recreational development is expected in the future. For areas below 3,000 feet in elevation it was estimated that the ultimate population density will average about four persons per square mile, and that per capita consumptive use of water will be about 70 gallons per day for a period of six months. In areas above 3,000 feet in elevation the same per capita use and density estimates were made, but it was assumed that the average period of water use will be of only three months' duration.

CONSUMPTIVE USE OF WATER

Estimates of the amounts of water consumptively used in the Colorado Desert Area were derived by applying the appropriate unit values of water use to the water service areas involved. The estimates represent the seasonal amount of water use under mean conditions of water supply and climate. Table 161 presents estimates of present consumptive use of applied water and precipitation on areas having water service. Table 162 presents the corresponding estimates for probable ultimate conditions of development, but excludes areas having rights in and to the waters of the Colorado River.

FACTORS OF WATER DEMAND

In addition to the amount of water consumptively used in a given service area, certain factors relating to the water requirements, such as necessary rates, times, and places of delivery of water, quality of water, losses of water, etc., must be given consideration in the design of water development works. In the Colorado Desert Area the most important of these demand factors are associated with the supply of water for irrigation. Those factors related to the supply of water for urban, suburban, recreational, and other uses are of secondary importance. The demand factors most pertinent to design of works to meet water requirements of the Colorado Desert Area are discussed in the following sections.

Monthly Distribution of Water Demands

Unlike nearly all other areas of the State, there is a considerable demand for irrigation water during the entire year in the Colorado Desert Area. The effective precipitation is very minor in amount, and irrigation water must be supplied on a continuous

TABLE 161

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF WATER ON PRESENT WATER SERVICE AREAS, COLORADO DESERT AREA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Unclassified areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
1	Twentynine Palms	5,600	600	negligible	900	300	6,800
2	Coachella Valley	119,000	12,700	300	7,200	0	126,000
3	Salton Sea	8,900	800	negligible	300	0	9,200
4	Imperial Valley	1,395,000	117,000	2,300	13,100	47 600	1,458,000
5	Colorado River	218,000	21,000	1,300	2,000	0	221,000
6	Lanfair Valley	0	0	0	0	0	0
	APPROXIMATE TOTALS	1,746,000	152,000	3,900	23,500	47,900	1,821,000

TABLE 162

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF WATER ON ULTIMATE WATER SERVICE AREAS, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots	Urban and suburban areas	Other water service areas	Approximate total consumptive use of applied water
Reference number	Name	Applied water	Precipitation	Applied water	Applied water	Applied water	
1	Twentynine Palms	340,000	46,400	1,800	7,000	1,500	350,000
2	Coachella Valley	128,000	11,300	400	21,800	200	150,000
3	Salton Sea	178,000	22,600	600	2,600	400	182,000
4	Imperial Valley	38,200	3,300	100	0	100	38,400
5	Colorado River	80,700	7,500	200	4,300	500	85,700
6	Lanfair Valley	396,000	61,000	1,800	4,400	400	403,000
	APPROXIMATE TOTALS	1,161,000	152,000	4,900	40,100	3,100	1,209,000

TABLE 163

DISTRIBUTION OF MONTHLY WATER DEMANDS, COLORADO DESERT AREA

(In per cent of seasonal total)

Locality and purpose	January	February	March	April	May	June	July	August	September	October	November	December	Total
Irrigation demand													
Coachella Valley ground water pumpage, 1936 through 1937	3.0	5.0	7.0	10.0	12.0	12.0	13.0	12.0	11.0	7.0	5.0	3.0	100.0
Coachella Canal diversion, 1951 through 1952	4.0	5.8	7.4	8.5	11.3	10.8	11.4	11.8	11.2	8.6	5.5	3.7	100.0
Imperial Valley, 1946 through 1949	6.1	6.7	9.5	10.1	9.7	9.4	9.4	8.0	8.0	10.3	7.4	5.4	100.0
Palo Verde Valley, 1946 through 1949	5.4	6.2	9.5	10.5	10.6	10.1	10.6	9.7	9.1	7.4	5.7	5.2	100.0
Urban demand													
Palm Springs, 1938 through 1948	6.7	7.1	7.6	9.8	8.9	7.9	8.9	9.1	9.2	9.3	8.4	7.1	100.0
Indio, 1948 through 1949	4.5	4.8	5.6	7.4	11.6	12.0	14.3	12.8	11.2	6.5	4.9	4.4	100.0
El Centro, 1953	7.7	7.0	7.8	7.3	8.3	10.1	12.2	11.0	9.4	6.7	5.9	6.6	100.0

basis in order to meet the consumptive requirements of the crops. Demand for irrigation water in the Colorado Desert Area varies from about 5 per cent of the seasonal total during the winter months to over 12 per cent in the summer months. Urban water demands have a variation similar to demands for irrigation supplies, although the gross amount of water involved is considerably less. Variation in demand for desert recreational areas has not been evaluated, but it is estimated that this type of water use is greatest during the desert vacation period from November through February. Representative data on monthly distribution of irrigation and urban water demands in the Colorado Desert Area are presented in Table 163.

Irrigation Water Service Area Efficiency

In the determination of irrigation water requirements in the Colorado Desert Area it was found to be desirable to estimate the over-all efficiency of irrigation practice in the various service areas. Irrigation water service area efficiency was measured by the ratio of consumptive use of applied irrigation water to the gross amount of irrigation water delivered to a service area. Present irrigation water service area efficiencies were estimated after consideration of geologic conditions of the service areas involved, their topographic position in relation to sources of water supply and to other service areas, consumptive use of water, irrigation efficiency actually achieved, usable return flow, and urban and suburban sewage outflow.

Numerous studies and investigations have been made by the United States Department of Agriculture and the University of California College of Agriculture of use of water and the resulting drainage problems in Coachella and Imperial Valleys. It has been found that individual farm irrigation efficiencies, in general, vary considerably with the crop, soil, and quality of the water supply. In the Imperial Valley all water is at the present time applied by surface application, and because of high saline content of the return water is, in most instances, used only once. The irrigated lands in Palo Verde Valley and in the Reservation Division of the Yuma Project, United States Bureau of Reclamation, lie immediately adjacent to the Colorado River. Irrigation water supplies are diverted into the distribution systems of the area by gravity. Water not consumptively used returns to augment the flow in the river. Under these circumstances water is somewhat lavishly used in accordance with the desires of the individual farm operator.

Additional factors affecting the estimates of probable ultimate irrigation water service area efficiencies were related to the location and extent of presently undeveloped irrigable lands and the increased cost of developing water. For purposes of illustration, the weighted mean values of all irrigation water service area efficiencies within each hydrographic unit of the Colorado Desert Area are presented in Table 164.

TABLE 164

ESTIMATED WEIGHTED MEAN IRRIGATION WATER SERVICE AREA EFFICIENCY WITHIN HYDROGRAPHIC UNITS, COLORADO DESERT AREA

(In per cent)

Hydrographic unit		Present	Probable ultimate
Reference number	Name		
1	Twentynine Palms	90	90
2	Coachella Valley	60	60
3	Salton Sea	90	80
4	Imperial Valley	50	60
5	Colorado River	85	85
6	Lanfair Valley	--	90

WATER REQUIREMENTS

As the term is used in this bulletin, water requirements refer to the amounts of water needed to provide for all beneficial uses of water and for irrecoverable losses incidental to such uses. Those water requirements of the Colorado Desert Area that are primarily nonconsumptive in nature are discussed in general terms in the ensuing section. Following this, water requirements of the area that are consumptive in nature are evaluated, both for present and for probable ultimate conditions of development.

Requirements of a Nonconsumptive Nature

The principal nonconsumptive requirements for water in this area are those for flood control, fish and wildlife, mining, and hydroelectric power development. All of these are minor in amount, particularly with relation to the amount of water necessary to meet requirements for irrigation water supplies. The nonconsumptive uses listed above are individually discussed in subsequent paragraphs.

Flood Control. There is a present need for flood control works in portions of the Colorado Desert Area, and it is anticipated that this need will increase with the growth of the area. Minor flood control works exist in the area at present, principally on the Whitewater River and for protection against flooding on the Colorado River. The effect of these works on the developed water supply is negligible. It is probable that other projects will be planned and constructed as development takes place in the future. The nonconsumptive requirements for water imposed by such flood control works will probably be minor in extent.

Fish and Wildlife. The fresh-water fishery of the Colorado Desert Area is limited almost entirely to that present in the Colorado River, but constitutes an important recreational facility in that region. While sport fishing is available along the length of the Colorado River in California, the major fishing areas are in the reach between Needles and Imperial Dam. The Colorado River and existing reservoirs are stocked with warm-water fishes, principally black bass, channel catfish, bluegill, and crappie, although trout can be found near the California-Nevada state line.

The California Department of Fish and Game has recently planted a variety of salt-water species of fish in the Salton Sea, in an attempt to augment the meager fauna of this large body of water. Surveys to date indicate that only one species, a croaker from the Gulf of Lower California, has survived and multiplied. The prolific breeding habits and the limited size of the croaker offer the possibility of an abundant supply of food for a larger salt-water game fish, should such be introduced. The Department of Fish and Game and the University of California at Los Angeles are cooperating in studies to develop the large recreational potential of this rich inland sea.

Under present conditions and with the limited available water supplies, streams other than the Colorado River rarely have perennial flow, thus definitely limiting their potential for fishery recreational use. Future development of storage reservoirs may expand fishery opportunities in the area.

The higher elevations of the Colorado Desert Area afford minor sport hunting of deer and small game. Migratory waterfowl frequent the Salton Sea, as well as the area of the Colorado River. At present there are four wildlife management areas in the Colorado Desert Area, of which the two in the Salton Sea area are supervised by the California Department of Fish and Game. The other two management areas, along the Colorado River, are supervised by the United States Fish and Wildlife Service. It is probable that such water as is necessary to maintain these wildlife management areas will be available from return flows from other areas.

Mining. The production and refining of gold, silver ores, lead, and copper in the Colorado Desert Area require very minor amounts of water, most of which is available for re-use. The amounts of water used for the washing of sand and gravel, the production of pumice, and mining of iron ore are negligible.

Hydroelectric Power. The nonconsumptive water requirements for hydroelectric power generation on the main stem of the Colorado River are not considered in this bulletin. Colorado River water conveyed by the All-American Canal to the Imperial and Coachella Valleys is used for the generation of power, but such use is incidental to its principal purpose, the import of water to the Colorado Desert Area for agricultural and municipal uses. Appreciable water requirements for generation of hydroelectric power are not expected to develop in the future, in view of prevailing water supply and topographic conditions.

Requirements of a Consumptive Nature

Estimates of present water requirements within hydrographic units of the Colorado Desert Area are presented in Table 165. Table 166 presents corre-

TABLE 165

ESTIMATED MEAN SEASONAL REQUIREMENTS FOR WATER ON PRESENT WATER SERVICE AREAS, COLORADO DESERT AREA

(In acre-feet)

Hydrographic unit		Irrigated lands	Farm lots	Urban and suburban areas	Other water service areas	Approximate total
Reference number	Name					
1	Twentynine Palms	6,200	100	900	300	7,500
2	Coachella Valley	198,000	600	7,200	0	206,000
3	Salton Sea	9,900	100	300	0	10,300
4	Imperial Valley	2,790,000	4,600	13,100	47,600	2,855,000
5	Colorado River	257,000	2,600	2,000	0	262,000
6	Lanfair Valley	0	0	0	0	0
	APPROXIMATE TOTALS	3,261,000	8,000	23,500	47,900	3,341,000

TABLE 166

PROBABLE MEAN SEASONAL REQUIREMENTS FOR WATER ON ULTIMATE WATER SERVICE AREAS, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acre-feet)

Hydrographic unit		Irrigated lands	Farm lots	Urban and sub-urban areas	Other water serv-ice areas	Approxi-mate total
Refer-ence number	Name					
1	Twentynine Palms	378,000	3,700	7,000	1,500	390,000
2	Coachella Valley	213,000	700	21,800	200	236,000
3	Salton Sea	223,000	1,300	2,600	400	227,000
4	Imperial Valley	63,700	200	0	100	64,000
5	Colorado River	94,900	500	4,300	500	100,000
6	Lanfair Valley	441,000	3,700	4,400	400	450,000
	APPROXIMATE TOTALS	1,414,000	10,100	40,100	3,100	1,467,000

sponding estimates for ultimate conditions of development, but excludes areas having rights in and to the waters of the Colorado River. These mean seasonal values represent the water other than precipitation needed to provide for beneficial consumptive use of water on irrigated lands, urban and suburban areas, and other water service areas, and for irrecoverable losses of water incidental to such use. The estimates were derived from consideration of the heretofore presented estimates of consumptive use of applied water, and of water service area efficiencies of hydrographic units.

Water requirements for the Twentynine Palms, Salton Sea, and Lanfair Valley Hydrographic Units take into consideration the re-use of portions of the applied water by storage and pumping from the subsurface basins. Present water requirements estimated for the Colorado River Hydrographic Unit are the sum of the beneficial consumptive use of Colorado River water and the estimated irrecoverable loss accompanying the diversion and use. The estimated water service area efficiency in this unit was established on this basis. At the persent time return flows from the Coachella Valley and Imperial Valley Hydrographic Units drain into the Salton Sea and are not available for subsequent use.

Supplemental Requirements

The probable ultimate supplemental water requirement in the Colorado Desert Area was evaluated as the difference between the present and ultimate water requirements.

The developed water supply available from the Colorado River was assumed to be the amount for which agencies within the State of California have entered into contracts with the United States Department of the Interior. Apportionment of this water supply among hydrographic units in the Colorado Desert Area was made on the basis of entitlements as set forth in the 1931 Seven-Party Agreement. The total annual quantity apportioned to this area in the aforesaid agreement was 4,150,000 acre-feet. This is believed to be sufficient to satisfy the ultimate water requirements of the lands having rights in and to the waters of the Colorado River.

Table 167 presents estimates of the probable ultimate supplemental water requirements in the Colorado Desert Area, except on lands having rights in and to the waters of the Colorado River.

TABLE 167

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL WATER REQUIREMENTS, COLORADO DESERT AREA

(Excluding lands having rights in and to the waters of the Colorado River)

(In acre-feet)

Hydrographic unit		Present	Probable ultimate
Reference number	Name		
1	Twentynine Palms	0	382,000
2	Coachella Valley	0	176,000
3	Salton Sea	0	217,000
4	Imperial Valley	0	64,000
5	Colorado River	0	99,100
6	Lanfair Valley	0	450,000
	APPROXIMATE TOTALS	0	1,388,000

CHAPTER X

SUMMARY

This chapter constitutes a summary, on a generalized state-wide basis, of the determinations of water utilization and requirements presented in the preceding chapters. It is prefaced by a brief description of California, its characteristics, and its potential for future growth and development, particularly as related to requirements for water. As has been stated, the area of the State was divided into seven major hydrographic areas in order to facilitate the present state-wide studies. The land areas of each of the seven hydrographic areas are given in Table 168. Locations and boundaries of the areas are shown on Plate 8.

TABLE 168

AREAS OF HYDROGRAPHIC AREAS, STATE OF CALIFORNIA

Reference number	Hydrographic area	Acres
1	North Coastal	12,500,000
2	San Francisco Bay	2,530,000
3	Central Coastal	7,221,000
4	South Coastal	6,995,000
5	Central Valley	38,050,000
6	Lahontan	20,970,000
7	Colorado Desert	12,420,000
	APPROXIMATE TOTAL	100,690,000

The State of California, bordering the Pacific Ocean over 10 degrees of latitude, occupies a commanding position on the western coast of North America. The towering peaks of the Sierra Nevada on the north and the wide deserts on the south form the eastern boundary of the State. With an average width of about 275 miles, California has a land area of over 100,000,000 acres. A great agricultural economy occupies the rich valley lands and much of the lower foothill area. Magnificent stands of timber are located on the mountain lands of the northern half of the State, and mineral resources, including construction materials, ores, and oil and gas, are found in many places. Excellent ports for world-wide commerce are located along the coast, inducing the growth of major industrial centers. About 7,000,000 acres are presently devoted to irrigated agriculture, and over 1,000,000 acres are occupied by urban and suburban developments. Many thousands of visitors to the State each year, as well as the majority of the resident population, utilize the outstanding recreational and scenic opportunities for vacationing, hunting, and fishing. The population of California increased from some 93,000 to about 10,600,000 in the century between 1850 and 1950, and is estimated to be well over 12,000,000 in 1955.

The general nature of the climate of California is the result of three controlling factors, the latitude, the influence of the Pacific Ocean, and the orientation and extreme range of topography. The situation of the Pacific high-pressure area with respect to the California coast determines the general effect of Pacific storms upon the weather. The influence of the ocean gives the immediate coastal areas a maritime climate. However, the unusually wide variations and abrupt discontinuities in the climate of California are due principally to the mountain ranges. Climatic conditions vary from mild and equable along the coast, to alpine-like in the high mountain areas of the Cascade Range and the Sierra Nevada, to hot and arid in the deserts of the southeast.

Precipitation mainly occurs during winter months, as rain at lower elevations and as snow in the higher mountain regions. Seasonal precipitation at sea level on the coast decreases from a depth of about 40 inches in the north to about 10 inches in the south. In the Central Valley it varies from about 38 inches at Redding to little over 6 inches at Bakersfield. In the Colorado Desert Area the average seasonal depth of precipitation on the valley floor is less than 4 inches.

Wet and dry periods lasting for several years, in which average precipitation departs far from the mean, are frequently experienced in California. One of the most severe recorded dry periods in most of the State extended from 1928 through 1934, and another severe drought was experienced in the southern part of the State from 1895 through 1904. The seasons of 1923-24 and 1930-31 were generally the driest throughout California since adequate records have been maintained.

The estimated mean seasonal natural runoff of California's streams is about 71,000,000 acre-feet. The major runoff contributions come from the North Coastal Area, which furnishes about 41 per cent of the total for the State, and from the Sacramento Valley portion of the Central Valley Area, which furnishes about 32 per cent. Runoff from the coastal streams closely follows the pattern of precipitation, while a substantial part of that from inland mountainous areas is delayed until the late spring and summer snowmelt period. Estimated mean seasonal runoff for the various hydrographic areas is presented in Table 169.

TABLE 169

ESTIMATED MEAN SEASONAL FULL NATURAL RUNOFF OF HYDROGRAPHIC AREAS, STATE OF CALIFORNIA

Reference number	Hydrographic area	Runoff	
		In acre-feet	In percent of total
1	North Coastal	28,890,000	40.8
2	San Francisco Bay	1,245,000	1.8
3	Central Coastal	2,448,000	3.4
4	South Coastal	1,227,000	1.7
5	Central Valley	33,640,000	47.5
6	Lahontan	3,177,000	4.5
7	Colorado Desert	221,000	0.3
	APPROXIMATE TOTALS	70,850,000	100.0

TABLE 170

ESTIMATED PRESENT AND PROBABLE ULTIMATE POPULATION WITHIN HYDROGRAPHIC AREAS, STATE OF CALIFORNIA

Reference number	Hydrographic area	Present (1950)	Probable ultimate
1	North Coastal	217,000	750,000
2	San Francisco Bay	2,555,000	13,460,000
3	Central Coastal	377,000	1,400,000
4	South Coastal	5,388,000	18,950,000
5	Central Valley	1,830,000	6,750,000
6	Lahontan	98,000	600,000
7	Colorado Desert	121,000	500,000
	APPROXIMATE TOTALS	10,590,000	42,410,000

The outstanding characteristic of natural stream runoff in California is the maldistribution of this basic resource. Over 72 per cent of the runoff occurs north of a line drawn roughly through Sacramento. In contrast, an estimated 77 per cent of the present water requirement and 80 per cent of the forecast ultimate requirement is found south of the same line.

As shown on Plate 4, at least 223 valley fill areas, which may or may not contain usable ground water, have been identified throughout California. Extensive ground water basins provide natural regulation for more than half of the water presently used for irrigation and urban purposes. Draft on many basins now exceeds replenishment, and in some instances the overdraft is of such magnitude as to threaten irreparable damage to these valuable storage reservoirs. However, the vast available underground storage capacity, estimated to be about 133,000,000 acre-feet in the Central Valley alone, will provide regulation for sufficient water to meet California's ultimate water requirement when operated coordinately with available surface reservoirs.

The population of California has almost doubled in the past 20 years, and has increased over 600 per cent since 1900. The widespread distribution of urban population is evidenced by the fact that in 1950 there were 19 cities with populations in excess of 50,000. Recent increases in population in suburban areas have in many cases been proportionately greater than within city limits. Table 170 presents the 1950 populations of the seven hydrographic areas and a forecast of their populations under ultimate conditions.

Industrial activity is a major influence in urban development of California, and is accelerating yearly. Many industries from eastern and midwest areas have established basic manufacturing plants here, and many others have located branch installations for final assembly of consumer products. Basic industries founded on local resources include the processing of agricultural products, ores, petroleum, steel, and timber. Aircraft production, utilizing materials largely imported from others parts of the country, is an outstanding processing industry.

Many outstanding projects for the purpose of developing and distributing the water supplies necessary for maintenance of the urban and industrial economy of California have been built in the past. Among these are the works to provide municipal supplies for the Cities of San Diego, Los Angeles, San Francisco and Oakland, and their environs, importing water from such distant sources as the Sierra Nevada and the Colorado River to the several communities. The indicated continuation of growth of population and industry points to even more imposing developments to meet the future water requirements for urban and industrial purposes.

Most of the commercial stands of timber in California are found in the North Coastal Area, and above an elevation of 3,000 feet on the western slopes of the Sierra Nevada, while less important stands occur throughout the State. These timbered areas are shown on Plate 6. The rate of timber growth on some 16,000,000 acres of lands susceptible of commercial development is estimated to be about 1,200,000,000 board feet per year. Under ultimate conditions and with adequate management, an annual sustained yield of about 3,800,000,000 board feet is considered possible. Many timber by-products are now processed within California, and it is expected that eventually most logging and milling residues will be used in manufacturing processes. The use of water by the timber industry constitutes only a relatively minor requirement. However, with the establishment of certain timber by-product industries, such as the manufacture of pulp and rayon, serious problems relating to waste disposal and its effect on water quality may arise.

The discovery of gold in 1848, which so spectacularly stimulated the development of the west, was followed by widespread production of gold and many other minerals in California. Because of recent unfavorable economic conditions, the mining of gold has fallen from its former commanding position, although substantial production still results from the working of auriferous gravels, largely by dredgers. The location and extent of the auriferous gravel deposits are shown on Plate 6. The early-day nonconsumptive water requirement for hydraulic mining of gold was substantial, but has declined to practically nothing. A possible future revival of the industry would impose a reservation on the available reservoir storage capacity of the State to impound debris and tailings.

Other than gold, the extractive industries of California now include the production of many metals and minerals, including a wide variety of industrial and construction materials, as well as the production of petroleum and natural gas. Iron ore processing at the Kaiser plant near Fontana provides the State with a basic steel industry. Petroleum extraction is centered principally in the southern part of the Central Valley and along the southern coast. Natural gas is likewise produced in these localities, and also in the north and central portions of the Central Valley. The processing of petroleum is centered around Los Angeles and San Francisco Bay. In general, these extractive industries do not impose significant water supply problems, their requirements being relatively small as related to other uses of water. However, as in the case of the timber industry, the problems of waste disposal inherent in some of these industries impose a threat on the maintenance of satisfactory water quality in streams and ground water basins.

By far the largest use of water in California is for agriculture, a condition that will continue to prevail even under conditions of ultimate development. The present use of water for all purposes other than agriculture is estimated to be only about 8 per cent of the total, and will increase to about 14 per cent ultimately. In 1950 there were 103 irrigation districts within the State, with a gross area of about 3,960,000 acres, of which about 3,080,000 acres were considered by the districts to be irrigable. In the same year approximately 6,300,000 acre-feet of water were delivered by these districts to over 2,170,000 acres of irrigated lands. The area of all irrigated lands in California, comprising nearly 6,900,000 acres in 1950, is approximately 25 per cent of the total area irrigated in the United States. A very large portion of the water to support irrigated agriculture in California has been developed as a result of the enterprise of local public districts. The Central Valley Project, which supplements irrigation supplies of the San Joaquin Valley with exchanged water from the Sacramento Valley, is an exception in this respect, having been constructed by the Federal Government. Major projects, surpassing the size and scope of any existing developments, will be required to enable desirable future expansion of irrigated agriculture in the State.

Electric power to meet the rapidly growing demands in California is produced by both fuel-electric and hydroelectric generation. At the present time the power demands of the State are being met principally by three major public utilities and several large municipal utilities. The production of these and other smaller privately and publicly owned systems is supplemented by power generated at several hydroelectric installations operated by the Federal Government. The total installed power capacity within the boundaries of the State in 1953 was about 6,800,000 kilowatts, of which approximately 2,870,000 kilowatts were for hydroelectric generation. The theoretical possible hydroelectric power capacity within the State is of the order of 10,700,000 kilowatts. The development of additional hydroelectric power is an important consideration in future water resource development planning.

The climatic advantages and wide variety of natural attractions of California provide unparalleled opportunities for recreational development. However, the amount of water actually consumed for domestic and service facilities in recreational areas is a very minor part of the aggregate requirement of the State. Waters used for boating, swimming, and other water sports are generally available naturally or as a result of works constructed for other purposes. The most substantial use of water in connection with recreation relates to the preservation and propagation of fish and wildlife, which use is nonconsumptive in nature. The principal consumptive use of water for recreational purposes is in connection with the maintenance of ponds and feeding areas for migratory wild fowl. It is anticipated that public demand for the preservation and enhancement of recreational facilities will be sufficient in most instances to assure provision of water supplies necessary for such purposes.

Flood control is important as it relates to the development of water resources in California. The sporadic nature of rainfall is conducive to major winter flood damage in many parts of the State. Accelerated snowmelt due to unseasonable early spring temperatures frequently creates problems in conserving and controlling the resultant runoff. The destruction and havoc caused by floods in California have frequently been accompanied by the economic anomaly of the wastage of huge amounts of water into the ocean in areas of deficient water supply. Major flood control activities include projects on the Sacramento and San Joaquin Rivers and extensive works in southern California, principally in the Los Angeles metropolitan area. Flood control in the past has been largely a joint endeavor between the United States, represented by the Corps of Engineers, the State, and local public interests. The magnitude of the flood problem can be gaged by the expenditure to date for such activities, which is estimated to be about $335,000,000 in the Sacramento and San Joaquin River Basins and in Los Angeles County. Additional large sums have been expended in other areas.

A multiplicity of other problems is involved in the development and use of the waters of California for beneficial purposes. These include the repulsion of sea water from underground basins, drainage of high watertable lands, maintenance of satisfactory salt balance in irrigated areas, and protection and maintenance of the quality of fresh waters. Solutions to these problems, and estimates of the amounts of water necessary to satisfy their requirements, must be developed in conjunction with future proposals for definite projects.

PRESENT AND ULTIMATE WATER SERVICE AREAS

Determinations of the location, nature, and extent of presently irrigated urban and suburban and other water service areas were made in all hydrographic areas of the State. At the same time, all lands were classified as to their suitability for development under probable ultimate conditions. The resulting data were utilized in determining the present and probable ultimate water requirements for all lands in California.

Since the lands of the Colorado Desert Area having rights in and to the waters of the Colorado River have available a sufficient water supply for their ultimate development estimates of ultimate water service areas and requirements for these lands were excluded from this bulletin.

Irrigated Lands

It was determined that under present conditions of development about 6,870,000 acres are irrigated in California in a given year, on the average. It was further estimated that a gross area of about 19,050,000 acres is suitable for irrigated agriculture, and that under ultimate conditions of development in the State a net area averaging about 16,250,000 acres will actually be irrigated.

On an areal basis, pasture, hay and grain, and alfalfa now constitute the dominant irrigated crops in California, and it was estimated that they will comprise about 43 per cent of the estimated ultimate crop pattern. However, the aggregate of other crops such as cotton, citrus, orchard, vineyard, and truck, is of equal or more importance economically. A summary of the presently irrigated acreage, segregated into various crop groups, is presented in Table 171. A similar crop pattern for probable ultimate conditions of development is presented in Table 172.

Urban and Suburban Water Service Areas

Under present conditions approximately 1,055,000 acres in California are devoted to urban and suburban types of land use. For the most part, the business,

TABLE 171

AREAS OF PRESENTLY IRRIGATED LANDS WITHIN HYDROGRAPHIC AREAS, STATE OF CALIFORNIA

(In acres)

Crop	Hydrographic area number and name							Approximate total
	1	2	3	4	5	6	7	
	North Coastal	San Francisco Bay	Central Coastal	South Coastal	Central Valley	Lahontan	Colorado Desert	
Alfalfa	24,400	4,100	30,900	42,500	585,000	96,200	203,000	986,000
Hay and grain	67,500	1,800	0	19,800	757,000	38,000	100,000	984,000
Pasture	97,500	8,500	24,500	41,200	795,000	81,700	8,200	1,057,000
Miscellaneous field crops	4,400	0	75,900	11,600[c]	370,000	2,000	85,400	549,000
Sugar beets	0	6,800	26,300	0	0	0	34,100	67,200
Beans	0	3,100	0	35,000	0	0	0	38,100
Rice	0	0	0	0	295,000	0	0	295,000
Truck	16,000	38,400	129,000	125,000	346,000	4,200	78,000	737,000
Orchard, general	2,800	84,500	38,300	19,700	387,000	5,600	1,500	539,000
Citrus	0	0	10,300	279,000	45,000	0	4,500	339,000
Walnuts	0	10,300	0	42,900	0	0	0	53,200
Vineyards	0	3,600	3,000	0	448,000	0	10,000	465,000
Cotton	0	0	0	0	723,000	0	34,000	757,000
Dates	0	0	0	0	0	0	6,100	6,100
Flowers	0	2,000	0	0	0	0	0	2,100
Net irrigated areas	213,000	163,000	338,000	617,000	4,751,000	228,000	565,000	6,875,000
Farm lots	4,100	[a]	5,900	[b]	108,000	2,800	7,900	129,000
Nonwater service areas	6,400	[a]	10,800	35,000	265,000	4,900	13,900	336,000
APPROXIMATE GROSS IRRIGATED AREAS	223,000	163,000	355,000	652,000	5,124,000	236,000	587,000	7,340,000

[a] Not segregated.
[b] Included in urban and suburban areas.
[c] Includes miscellaneous crop types not otherwise segregated.

TABLE 172

PROBABLE ULTIMATE AREAS OF IRRIGATED LANDS WITHIN HYDROGRAPHIC AREAS, STATE OF CALIFORNIA

(In acres)

Crop	Hydrographic area number and name							Approximate total
	1	2	3	4	5	6	7	
	North Coastal	San Francisco Bay [a]	Central Coastal	South Coastal	Central Valley	Lahontan	Colorado Desert [d]	
Alfalfa	124,000		75,600	60,100	1,112,000	647,000	181,000	2,200,000
Pasture	317,000		164,000	146,000	1,513,000	854,000	14,600	3,009,000
Hay and grain	297,000		250,000	68,600	1,052,000	899,000	95,000	2,662,000
Miscellaneous field crops	34,200		202,000	45,000 [b]	995,000	6,300	43,000	1,326,000
Sugar beets			69,000		320,000	55,100	800	445,000
Beans				72,900				72,900
Rice					738,000			738,000
Truck	51,800		219,000	193,000	524,000	53,200	68,400	1,109,000
Orchard, general	28,100		113,000	59,900	708,000	42,200	14,400	966,000
Citrus			32,600	325,000	104,000		10,500	472,000
Walnuts				53,000				53,000
Vineyard	16,900		41,200		710,000	54,800	40,900	864,000
Cotton					2,261,000		3,600	2,265,000
Dates							2,500	2,500
Net irrigated areas	869,000	62,400 [a]	1,166,000	1,024,000	10,040,000	2,612,000	475,000	16,250,000 [c]
Farm lots	14,700	1,400	19,500	35,800	166,000	56,300	10,100	304,000
Nonwater service areas	174,000	2,000	183,000	96,400	1,547,000	430,000	67,100	2,500,000
APPROXIMATE GROSS IRRIGATED AREAS	1,058,000	65,800	1,368,000	1,156,000	11,750,000	3,098,000	552,000	19,050,000

[a] Crop pattern not forecast. Total without reclamation of tidelands.
[b] Includes miscellaneous crop types not otherwise segregated.
[c] Total of segregated crop pattern, except San Francisco Bay Area, is 16,190,000 acres.
[d] Excluding lands having rights in and to waters of the Colorado River.

commercial, and industrial establishments and surrounding homes included in this classification receive a municipal type of water supply. It is anticipated that future urban and suburban growth in most regions of the State will parallel the development of agricultural lands. Metropolitan areas, however, particularly those bordering the Pacific Ocean, may be expected to respond to national and world-wide economic conditions, in addition to those created by the expansion of California as an agricultural state. It is estimated that urban and suburban water service areas under ultimate conditions of development will occupy about 3,435,000 acres.

Other Water Service Areas

The remaining lands of California, other than those that are irrigated or urban and suburban in character, were not classified in detail with regard to water service. Of a total of about 92,760,000 acres of such remaining lands, approximately 182,000 acres actually receive water service at the present time. These relatively minor present water service areas, herein termed "Unclassified," consist largely of scattered developments in national forests and monuments, public beaches and parks, private recreational areas, wild fowl refuges, and military reservations.

It is estimated that under probable conditions of ultimate development, approximately 76,910,000 acres of such lands will be served with water in amounts sufficient for their needs. No attempt was made to segregate these "other water service areas" in detail with regard to the nature of their probable ultimate water service. By far the greater portion of the lands is situated in rough, mountainous terrain, much of which is presently unaccessible. It is expected that even under conditions of ultimate development this portion will be only sparsely settled and will have only very minor requirements for water service.

Summary

Table 173 summarizes data relative to present water service areas in the various hydrographic areas of California, classified by broad land usage groupings. Similar data relating to probable ultimate conditions of development are given in Table 174.

UNIT VALUES OF WATER USE

It is anticipated that the values of water use and requirement estimated for this bulletin will be used in connection with long-range water resources planning. The unit values expressed, therefore, are those that would occur under mean conditions of water supply and climate, and represent the average use of water when an adequate water supply is available. They do not reflect possible effects of any present shortages in water supply.

TABLE 173

SUMMARY OF PRESENT WATER SERVICE AREAS WITHIN HYDROGRAPHIC AREAS, STATE OF CALIFORNIA

(In acres)

Reference number	Hydrographic area	Gross irrigated area	Urban and suburban areas	Unclassified areas	Approximate total
1	North Coastal	223,000	18,500	19,500	261,000
2	San Francisco Bay	163,000	225,000	50,100	438,000
3	Central Coastal	355,000	48,400	12,200	416,000
4	South Coastal	652,000	547,000	1,200	1,200,000
5	Central Valley	5,123,000	191,000	84,700	5,399,000
6	Lahontan	236,000	10,300	4,500	250,000
7	Colorado Desert	587,000	14,200	10,000	611,000
	APPROXIMATE TOTALS	7,339,000	1,054,000	182,000	8,575,000

TABLE 174

SUMMARY OF PROBABLE ULTIMATE WATER SERVICE AREAS WITHIN HYDROGRAPHIC AREAS, STATE OF CALIFORNIA

(In acres)

Reference number	Hydrographic area	Irrigable lands	Urban and suburban areas	Other water service areas	Approximate total
1	North Coastal	1,058,000	53,000	11,390,000	12,500,000
2	San Francisco Bay [a]	65,800	1,250,000	1,222,000	2,538,000
3	Central Coastal	1,368,000	138,000	5,715,000	7,221,000
4	South Coastal	1,156,000	1,611,000	4,228,000	6,995,000
5	Central Valley	11,750,000	292,000	26,010,000	38,050,000
6	Lahontan	3,098,000	53,700	17,820,000	20,970,000
7	Colorado Desert [b]	552,000	13,700	10,530,000	11,100,000
	APPROXIMATE TOTALS	19,050,000	3,411,000	76,910,000	99,370,000

[a] Without reclamation of tidelands.
[b] Excluding lands having rights in and to waters of the Colorado River.

A comprehensive study was made of available experimental data on consumptive use of irrigation water and of records of irrigation water deliveries and return flows. Investigation was also made of the prevailing irrigation practices in the several parts of the State. For most of California, unit seasonal values of consumptive use of applied irrigation water for the various crop groups were estimated by a method developed mainly by Harry F. Blaney and Wayne D. Criddle of the federal Soil Conservation Service. However, the basic method of these authorities was modified somewhat to meet the special needs of the present investigation, and in the light of the cited study of irrigation records and practices.

Unit values of water use in urban and suburban areas, other than in the San Francisco Bay Area and in most of the South Coastal Area, generally were estimated from records of present delivery and disposal of water, utilizing data from private and public water service agencies. Although there are large variations in per capita water deliveries to various cities, analysis disclosed no firm trends in the amount of the deliveries as related to metered or unmetered water service, or as related to the cost of water to the consumer. More important factors in this respect seemed to be the climatological characteristics, the abundance or scarcity of water, and the nature and habits of the communities. The records of water delivery indicated that in recent years there has been an increase in the per capita urban requirement, and that the trend is continuing. A substantial part of the increase probably results from development of modern water-using appliances. In some communities, also, a growing industrialization accounts for part of the increase. To provide for this trend, the probable ultimate unit values of water deliveries to urban and suburban areas generally were increased 10 per cent over present values.

For the metropolitan areas in and around San Francisco, Los Angeles, and San Diego, as well as for most of the remaining urban areas in the South Coastal Area, unit values of present water use were estimated by a sampling procedure. An inventory was made of measured water deliveries in sample areas representative of each urban type. In most cases, the probable ultimate unit values were estimated by adjusting the present values, the adjustments being based upon indicated trends for each urban type.

Estimates of unit values of water use in areas other than irrigated, urban and suburban, or metropolitan, were based largely on records or estimates of present water delivery. By the nature of the activities involved, water utilization in most of these other water service areas is not adaptable to areal classification, and the unit values of water use consisted of per capita or per unit of production values. In areas outside of specifically classified types of development, ultimate unit values were generally expressed on a per capita basis, assumptions being made as to densities of ultimate population. For lands above an elevation of 3,000 feet it was assumed that occupancy would be limited to a few months of the year, thus reducing the effective seasonal unit value of water use, while lands below that elevation were assumed to be occupied for longer periods.

Evaluation of unit values of water use by urban types was generally based on the assumption that water delivery constitutes an approximate equivalent measure of consumptive use of applied water and the unavoidable losses sustained in delivery and disposal. Exceptions to this were made for unsewered absorptive portions of the South Coastal Area, where allowances were taken for return flow and re-use of sewage. Water deliveries to unclassified and other water service areas were likewise considered to be the measures of consumptive use of applied water.

Estimated weighted mean seasonal unit values of consumptive use of applied water in the seven major hydrographic areas of the State are presented in

Tables 175 and 176, respectively, for present and probable ultimate conditions.

TABLE 175

ESTIMATED PRESENT WEIGHTED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF APPLIED WATER, STATE OF CALIFORNIA

(In feet of depth)

Reference number	Hydrographic area	Irrigated lands	Farm lots	Urban and suburban areas
1	North Coastal	1.5	1.0	1.1
2	San Francisco Bay	1.3	a	1.6
3	Central Coastal	1.3	0.5	1.0
4	South Coastal	1.5	b	0.6
5	Central Valley	2.0	0.5	0.7
6	Lahontan	2.0	0.5	0.6
7	Colorado Desert	3.1	0.5	1.7
	WEIGHTED MEAN	2.0	0.5	0.9

a Included in "Unclassified Areas."
b Included in "Urban and Suburban Areas."

TABLE 176

PROBABLE ULTIMATE WEIGHTED MEAN SEASONAL UNIT VALUES OF CONSUMPTIVE USE OF APPLIED WATER, STATE OF CALIFORNIA

(In feet of depth)

Reference number	Hydrographic area	Irrigated lands	Farm lots	Urban and suburban areas	Other water service areas
1	North Coastal	1.3	0.8	1.6	less
2	San Francisco Bay	0.9	2.0	2.2	than
3	Central Coastal	1.2	0.5	1.4	0.01
4	South Coastal	1.5	0.8	0.8	in
5	Central Valley	2.0	0.5	1.3	all
6	Lahontan	2.0	0.5	1.0	areas
7	Colorado Desert	2.7	0.5	2.9	
	WEIGHTED MEAN	1.9	0.6	1.4	

CONSUMPTIVE USE OF APPLIED WATER

The amount of applied water consumptively used was estimated by applying the appropriate unit value of water use to the acreage of each of the various classes and types of land use, and totaling for each service area. These estimates are summarized by major hydrographic areas of the State in Tables 177 and 178, for present and probable ultimate conditions, respectively.

WATER REQUIREMENTS

In broad generalization, the amount of the requirement for water of a consumptive nature was derived by dividing the amount of consumptive use of applied water by an appropriate efficiency factor, the factor being chosen to account for unavoidable losses within the service area under consideration. Most nonconsumptive requirements for water, however, are not readily susceptible of evaluation except as they relate to actual water development projects, and should be evaluated with consideration to all water requirements at the time projects are implemented. For this reason, nonconsumptive water requirements are discussed only generally in this bulletin and are not summarized in this chapter.

The requirement for irrigation water was estimated as the sum of the products of appropriate unit values of consumptive use of applied irrigation water and the areas of the various irrigated crop types, divided by estimated irrigation water service area efficiencies, or by equivalent procedure. In many instances, data available from agencies serving irrigation water per-

TABLE 177

ESTIMATED MEAN SEASONAL CONSUMPTIVE USE OF APPLIED WATER ON PRESENT WATER SERVICE AREAS, STATE OF CALIFORNIA

(In acre-feet)

Reference number	Hydrographic area	Irrigated lands	Farm lots	Urban and suburban areas	Unclassified areas	Approximate total
1	North Coastal	317,000	4,000	20,900	4,500	346,000
2	San Francisco Bay	209,000	a	352,000	35,600	597,000
3	Central Coastal	426,000	3,100	47,400	14,600	491,000
4	South Coastal	919,000	b	338,000	2,400	1,259,000
5	Central Valley	9,508,000	54,400	138,000	105,000	9,805,000
6	Lahontan	464,000	1,400	6,100	14,100	486,000
7	Colorado Desert	1,746,000	3,900	23,500	47,900	1,821,000
	APPROXIMATE TOTALS	13,590,000	66,800	926,000	224,000	14,810,000

a Included in "Unclassified Areas."
b Included in "Urban and Suburban Areas."

TABLE 178

PROBABLE MEAN SEASONAL CONSUMPTIVE USE OF APPLIED WATER ON ULTIMATE WATER SERVICE AREAS, STATE OF CALIFORNIA

(In acre-feet)

Reference number	Hydrographic area	Irrigated lands	Farm lots	Urban and suburban areas	Other water service areas	Approximate total
1	North Coastal	1,131,000	12,200	85,200	83,500	1,312,000
2	San Francisco Bay a	72,000	2,800	2,747,000	2,500	2,824,000
3	Central Coastal	1,432,000	9,800	198,000	23,200	1,663,000
4	South Coastal	1,568,000	28,600	1,264,000	16,000	2,877,000
5	Central Valley	20,100,000	83,600	372,000	301,000	20,860,000
6	Lahonton	5,151,000	28,200	53,700	64,800	5,298,000
7	Colorado Desert b	1,161,000	4,900	40,100	3,100	1,209,000
	APPROXIMATE TOTALS	30,610,000	170,000	4,760,000	494,000	36,040,000

a Without reclamation of tidelands.
b Excluding lands having rights in and to waters of the Colorado River.

mitted direct derivation of the present efficiency factor. Where such data were not available or applicable, the efficiency of water use was estimated on the basis of available information on conveyance and distribution losses, re-use of return flow, flushing water required to maintain salt balance, and topographic and geologic conditions affecting the application and use of irrigation water. Of primary importance among the topographic and geologic factors are the existence, extent, and type of ground water basins, and their positions with relation to sources of water supply and to other water service areas.

The water requirements of urban and suburban areas, other than in the South Coastal and San Francisco Bay Areas, were estimated as the sums of the products of appropriate unit values of water delivery and the determined total areas of urban and suburban land use. Urban water requirements of the metropolitan areas in and around Los Angeles, San Francisco, and San Diego were estimated as the sum of the products of appropriate unit values of water delivery, times the areas of the various types of urban land use, multiplied by factors to account for water losses in conveyance and delivery throughout the water systems. Additionally, in portions of the South Coastal Area the re-use of unconsumed urban water delivered on absorptive lands was taken into account, involving consideration of the status of sewerage.

For water service areas designated "unclassified" under present conditions, and for those classed as "other water service areas" under ultimate conditions, water requirements were estimated as the sum of the products of derived unit values of water delivery and appropriate factors of population or unit of production.

The total requirement for water in each service area was taken as the sum of the individual requirements for the several classes of water use, due account generally being taken of usable return flow from applied water within the area. Similar consideration was made in evaluating total water requirements of larger measures of land area. Estimates of the present and probable ultimate mean seasonal consumptive requirements for water by major hydrographic areas are presented in Table 179.

SUPPLEMENTAL WATER REQUIREMENTS

In areas with a present deficiency in water supply development, standard procedures were utilized to evaluate the present safe yield. By subtracting this value from the determined present water requirement, the supplemental water requirement was derived. Available data on which to base estimates of present safe yield were often inadequate, and the resulting estimates of supplemental requirement are necessarily subject to error. However, they are believed to be sufficiently reliable for their particular purpose, which is to provide information regarding the magnitude of water supply surpluses or deficiencies in the various parts of California in order to permit development of the broad pattern of The California Water Plan.

Ultimate supplemental water requirements were evaluated as the difference between present and ultimate requirements for water, plus the present supplemental water requirement in such areas as experience a present deficiency. The possible additional yield of the existing water supply works over the present requirement of the area served was not credited to reduction of the ultimate supplemental water requirement, except for the water allocated from the Friant-Kern, Madera, and Contra Costa Canals. The difficulties inherent in defining and determining accurately the amount of present surface yield, and in allocating the surplus to specific water service areas

TABLE 179

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL REQUIREMENTS FOR WATER, STATE OF CALIFORNIA

(In acre-feet)

Hydrographic unit		Irrigated lands		Farm lots		Urban and suburban areas		Other water service areas		Approximate totals	
Reference number	Name	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate	Present	Probable ultimate
1	North Coastal	488,000	1,917,000	4,200	15,400	21,000	85,300	4,500	83,500	518,000	2,101,000
2	San Francisco Bay	301,000	98,300 [a]	[b]	2,800 [a]	388,000	3,021,000 [a]	35,600	2,500 [a]	725,000	3,124,000 [a]
3	Central Coastal	641,000	2,217,000	6,100	19,600	47,400	198,000	14,600	23,200	709,000	2,458,000
4	South Coastal	1,020,000	1,856,000	[c]	45,000	885,000	3,635,000	2,400	16,100	1,907,000	5,552,000
5	Central Valley	12,700,000	22,820,000	109,000	167,000	277,000	741,000	105,000	300,000	13,190,000	24,030,000
6	Lahontan	712,000	6,607,000	3,000	56,000	12,000	107,000	14,000	65,000	741,000	6,835,000
7	Colorado Desert	3,261,000	1,414,000 [d]	8,000	10,100 [d]	23,500	40,100 [d]	47,900	3,100 [d]	3,341,000	1,467,000 [d]
	APPROXIMATE TOTALS	19,120,000	36,930,000	130,000	316,000	1,654,000	7,827,000	224,000	493,000	21,130,000	45,570,000

[a] Without reclamation of tidelands.
[b] Included with "Other Water Service Areas."
[c] Included with "Urban and Suburban Areas."
[d] Excluding lands having rights in and to waters of the Colorado River.

prior to completion of a comprehensive ultimate plan, were such as to preclude their consideration in studies for the present bulletin.

It should be noted that the supplemental water requirement for a major hydrographic area, or for a stream basin within that area, is not necessarily equal to the sum of the individual supplemental requirements of the included areas. This follows from the fact that there is usually opportunity for downstream re-use of return flows from water applied on upstream areas, thus reducing the aggregate supplemental requirement for the hydrographic area or stream basin taken as a whole.

Estimates of present and probable ultimate mean seasonal supplemental requirements for water in the major hydrographic areas of California are presented in Table 180.

TABLE 180

ESTIMATED PRESENT AND PROBABLE ULTIMATE MEAN SEASONAL SUPPLEMENTAL REQUIREMENTS FOR WATER, STATE OF CALIFORNIA

(In acre-feet)

Reference number	Hydrographic area	Present	Probable ultimate
1	North Coastal	0	1,583,000
2	San Francisco Bay	32,000	2,209,000
3	Central Coastal	184,000	1,902,000
4	South Coastal	395,000	4,040,000
5	Central Valley	1,785,000	11,740,000
6	Lahontan	279,000	6,373,000
7	Colorado Desert*	0	1,388,000
	APPROXIMATE TOTALS	2,675,000	29,230,000

* Excluding lands having rights in and to the waters of the Colorado River.

ULTIMATE EXPORT AND IMPORT OF WATER

Table 181 presents a summary of estimates of runoff, yield, requirement, and surplus or deficiency of water in the several parts of California under probable ultimate conditions of development. As has been stated, the estimates of safe yield of the ultimate water supply development are necessarily very tentative at this stage of planning, and cannot be actually fixed until final determination of The California Water Plan. However, they are believed to be adequate for present planning purposes.

The yield estimates in Table 181 contemplate the full development of local water supplies for local use, as well as the supplies developed for export from areas of surplus to areas of deficiency. In addition to the full use of surface reservoir storage capacity for regulation of stream flow, the estimates of safe yield are based on a substantial coordinated use of ground water storage capacity for this purpose.

The estimates of surplus and deficiency in Table 181 do not consider exports or imports of water between major hydrographic areas developed in connection with present rights. Rather, they are based on the inherent water resource and requirement characteristics of the areas. However, existing developments and present rights will be given primary consideration in The California Water Plan.

The data presented in Table 181 not only illustrate the basic geographic problem of water supply development in California, but indicate the nature of the solution to that problem. The full amount of the rights of California in and to the waters of the Colorado River must be protected to meet requirements within the State. In addition, an average of approximately 23,000,000 acre-feet of water per season ultimately must be developed from the North Coastal Area and from the Sacramento River Basin of the Central Valley Area, and exported to the remaining water-deficient portions of the State. This conclusion provides the basis for the broad pattern of The California Water Plan.

TABLE 181

SUMMARY OF ESTIMATED ULTIMATE MEAN SEASONAL EXPORTS AND IMPORTS OF WATER IN CALIFORNIA

(In acre-feet)

Reference number	Hydrographic area	Mean runoff	Safe yield	Water requirement	Surplus, available for export	Deficiency, to be met by import
1	North Coastal	28,890,000	13,860,000	2,101,000	11,760,000	0
2	San Francisco Bay	1,245,000	439,000	3,124,000	0	2,685,000
3	Central Coastal	2,448,000	1,109,000	2,458,000	0	1,349,000
4	South Coastal	1,227,000	1,190,000	5,552,000	0	4,362,000
5	Central Valley					
	Sacramento River Basin	22,390,000	19,040,000	7,720,000	11,320,000	0
	San Joaquin River and Tulare Lake Basins	11,250,000	9,560,000	16,310,000	0	6,750,000
6	Lahontan					
	Area north of Mono Lake Basin	1,843,000	448,000	1,361,000	0	913,000
	Mono Lake Basin and area to south	1,334,000	726,000	5,474,000	0	4,748,000
7	Colorado Desert	321,000	78,000	5,617,000	0	5,539,000
	California's rights in and to waters of the Colorado River		5,362,000		5,362,000	
	Requirement for operation of works in Sacramento-San Joaquin Delta, and for transmission losses			2,093,000		2,093,000
	APPROXIMATE TOTALS	70,850,000	51,810,000	51,810,000	28,440,000	28,440,000

STATE OF CALIFORNIA
GOODWIN J. KNIGHT
GOVERNOR

PUBLICATION OF
STATE WATER RESOURCES BOARD

Bulletin No. 2

WATER UTILIZATION AND REQUIREMENTS OF CALIFORNIA

Volume II
APPENDIXES AND PLATES

June, 1955

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APPENDIX A

A PRELIMINARY PROJECTION OF CALIFORNIA CROP PATTERNS FOR ESTIMATING ULTIMATE WATER REQUIREMENTS

BY DAVID WEEKS
Professor of Agricultural Economics
University of California
January 15, 1954

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A PRELIMINARY PROJECTION OF CALIFORNIA CROP PATTERNS FOR ESTIMATING ULTIMATE WATER REQUIREMENTS

INTRODUCTION

The acreage, kind, and location of the different agricultural crops grown in California may be called the "California Crop Pattern." Similarly, any area within the State may have a crop pattern. The different crop patterns will use different total amounts of water per acre because each of the different crops within a given pattern requires a specific amount of water annually. Projection of the ultimate water required for irrigation in California, therefore, has required a preliminary projection of the crop pattern. Like most projections of this kind, much more knowledge of the past, present, and future is necessary than is available. Furthermore, like other work of this nature, time and funds available usually are not adequate to make an exhaustive analysis, and, if such an analysis were made, there might be doubt as to how much it would reduce the error always inherent in such work. The analysis reported herein, therefore, is not exhaustive.

In the course of the next few decades, most of the land area of California now considered irrigable probably will have been provided with irrigation facilities. When water actually is applied to all of these areas and when all urban areas "have been expanded to a foreseeable limit," then the State land and water resources may be said to have reached a condition of *initial full development*.

Beyond this initial stage, irrigated land area and water supply will tend to become more and more nearly constant. The concept of *ultimate development* thus becomes one of a fixed land and water supply. Actual water use will be limited by its supply. The area irrigated will be limited by the amount of land available which is irrigable. Thus, in the long run, water used at the stage of initial full development will approximate the amount used at the stage of ultimate development.

After the stage of initial full development has been passed, changes undoubtedly will continue to take place in the pattern and intensity of land and water use. Increases in demand for products of irrigated land will be met thereafter by increasing intensity of production, introduction of new methods, or by meeting increasing demand by the substitution of other products. The crop pattern will be the result of (1) land and water supply, (2) various costs, and (3) demand for the products. In the long run, agricultural prices may not be a determinant of land and water use but may be determined in the same process. But more on this point will follow later.

Scope and General Procedure

The point of departure in making the projections of agricultural land uses in these studies has been the irrigated crop pattern compiled by the State Division of Water Resources during and pertaining to the period 1946-1950.

Supplementing this irrigated crop compilation are the statistics of crop acreages tabulated by the California Crop Reporting Service. These statistics have made possible a comparison and check with the compilation mentioned above. Furthermore, they give a basis, together with the census, for making an estimate of the total acreages of given crop groups which have been irrigated. The Agricultural Census, which is characteristically underestimated, nevertheless provides a fairly satisfactory sample from which trends (1909-1952) in percentage of the different crop groups irrigated have been estimated.

From these trends in percentages or cropland irrigated and statistics of total crop acreages, the acreages of the different crop groups which have been irrigated have been calculated historically for a period of three or four decades, the period depending upon the availability of statistics. Trends of these irrigated acreages have been projected on the basis of assumptions, criteria, and reasoning given below.

General Assumptions

As indicated above, assumptions have been necessary to bridge gaps in available information. Some of these assumptions apply to the general procedure; others pertain to specific crops or groups of crops. The general assumptions may be enumerated as follows:

1. It is assumed on the basis of reasoning previously expressed that the water requirements for the "ultimate" crop pattern will be approximately equal to that required for the crop pattern at the stage of initial full development of the irrigable area.
2. The percentage distribution of crops for the state as a whole at the stage of initial full development has been assumed to be approximately the same as that obtained from a tentative projection of the crop pattern for 1980. *No specific*

point of time, however, has been assumed at which initial full development will be attained.

3. Although in the long run, irrigation development and population growth in California are interdependent, one upon the other, during the next few decades—the years during which the stage of full development of the irrigable area is being attained—it is assumed that population growth in California and in the United States as a whole will be the dominant factor in the demand for irrigated land. This assumption is partially supported by statistics.
4. International trade becomes an important factor in relation to cotton, sugar, rice, wheat, raisins, and prunes.
5. Price regulations, acreage quotas, and special state legislation are significant factors in explaining short-run changes in acreage but are assumed to have little effect upon long-run changes and trends. These factors could become important, however, in establishing a long-term trend—historical or projected.
6. It is assumed that present-day changes in yields per acre, technological processes, and economic efficiency are represented adequately in the trends of acreages and production. Unforeseen, revolutionary changes could upset these trends. It is assumed, however, that future changes in technological processes will be at the same rate as those reflected in these trends.

POPULATION

There has been a growing tendency to try to avoid projections to a specific stage in the future because of the uncertainties involved. As this report is being written, skepticism has reached a new high because of the failure of many of the projections of United States population which have been made during the past three decades. Opinions have been held by certain population experts that the sharp decline in birth rates characteristic of the late 1920's and early 1930's would continue. These errors of judgment dominated an important segment of professional thought but as early as 1929 were rejected by specialists cooperating with the Division of Water Resources.[1]

Dr. Joseph S. Davis in 1949, looking back on the results of recent population projections, stated that the dominant source of error in projecting population growth "has been the undue weight that has been consistently given to past trends in fertility rates, especially since 1920, and to what have proved ill-founded opinions that these trends would continue, or, if interrupted, soon be resumed."[2]

[1] See California Division of Water Resources. "Permissible Rates of Irrigation Development in California." 1930, p. 28. (Bul. 35)

[2] Davis, Joseph S. "Population Upsurge in the United States." Stanford University Food Research Institute, 1949. One leaf pamphlet no. 12, p. 39.

Attention already has been called to the fact that it is not so important to predict *when* the stage of initial full development of the irrigable areas will be reached as it is to determine the approximate pattern of land use that is most likely to accompany that stage. It is essential, however, to note the changes in the different types of land utilization in terms of their percentages of the total area under cultivation and the total area irrigated and in relation to the passage of time, at least approximately. Some assumptions, therefore, with respect to the rate of population growth in the United States and in California, are essential as a preliminary step in projecting the California crop pattern.

United States Population Growth—Historical and Projected Trends

As indicated previously, most of the recent projections of the United States population growth have required revisions upward. The United States population at the end of each decade from 1910-1950, together with a "medium" projection in 1980, is presented in Table 1 and is shown graphically in Figure 1A. Throughout eight decades up to 1950, the percentage rate of increase per decade had been declining. These declining rates of increase are the end results of an intricate changing pattern of birth rates and of death rates; of marriage rates and of divorce rates; of immigration rates and emigration rates; of occupational and geographical distribution; of changes in the age, sex, and nativity distribution among the different age groups in the population; and of many other changing internal characteristics. They also are the end results of conditions external to the population itself. They reflect social trends, general economic conditions, and, most important of all, basic resources and their rates and manner of development and utilization. Judgment on these important external influences is far more critical in a population projection than meticulous precision on any one of the internal factors. These more fundamental factors, the external ones, are the causes of changes within the population. They have been given very meager emphasis, however, in population analyses and projections. As a result, population estimates, even very recent ones, have required continual revision.

Reference already has been made to a review of the results of population forecasting written by Dr. Joseph S. Davis. In a later report he gives, as a minimum which he states certainly will be exceeded, 180,000,000 as the population of the United States in 1980 and 193,000,000 for the same year which, he states, does not look inherently improbable.[3]

In May, 1950, the United States Bureau of the Census released to the President's Water Resources Policy Commission some preliminary projections of

[3] Davis, Joseph S. "Agriculture and the New Population Outlook." Paper read before the National Agricultural Credit Commission, Chicago, Illinois, January 30, 1950.

TABLE 1
UNITED STATES POPULATION TRENDS

Decade	Population, end of decade: Enumerated and projected	Population, end of decade: Trend	Increase during decade: Enumerated and projected		Increase during decade: Trend	
	1	2	3	4	5	6
	thousands	thousands	thousands	per-cent	thou-sands	per-cent
1900-1910	91,972	91,972	-------	------	------	------
1910-1920	105,711	107,076	13,739	14.9	15,104	16.4
1920-1930	122,775	122,180	17,064	16.1	15,104	14.1
1930-1940	131,669	137,284	8,894	7.2	15,104	12.4
1940-1950	151,132	152,388	19,463	14.8	15,104	11.0
	Projections					
1950-1960	169,371	167,492	18,239	12.0	15,104	9.9
1960-1970	182,600	182,596	13,229	7.8	15,104	9.0
1975	190,101	-------	-------	------	------	------
1970-1980	197,700	197,700	15,100	8.3	15,104	8.3

SOURCES:
Col. 1: Population 1910-1940 from 16th Census of the United States, 1940, Population, vol. 1. p. 14, Table 3.
Population 1950 is total population = 150,697,361 plus estimates of forces overseas. Bureau of the Census Release Series P-25, no. 46, February 19, 1951.
Projection for 1960 and 1975 from Hagood, Margaret Harmon, and Jacobs Siegel. Projections of the Regional Population of the United States to 1975. Agr. Econ. Research, vol. III, no. 2, April, 1951. "Medium Series" of Table 3, p. 47. "The Low Series" gives 165,616,000 and the "High Series," 225,310,000 for 1975.
A straight line through the 1910 population and the 1975 projection to 1980 gives an approximate "fit" and is used here as the basis for the trend 1910-1980 and for projecting the 1980 population.
Col. 2: Trend of items of column 1.
Col. 3: Differences between items of column 1.
Col. 4: Items of column 3 divided by population at beginning of corresponding decade, column 1 x 100.
Col. 5: Constant difference in trend of column 2.
Col. 6: Items of column 5 divided by trend at the beginning of corresponding decade, column 2 x 100.

the United States population. These projections for 3 levels for 1960 were 161,000,000, 169,000,000, and 180,000,000, respectively, and for 1975 they were 165,000,000, 190,000,000, and 225,000,000, respectively.[4]

These projections were all in sharp contrast to those used by the United States Department of Agriculture in its report, "Long Range Agricultural Policy," presented to the Committee on Agriculture of the House of Representatives as late as 1948. In 1951, Jacob Siegel of the Bureau of the Census and Margaret Hagood of the United States Department of Agriculture published a projection for 1975, giving a "low" of 165,616,000, a "medium" of 190,101,000, and a "high" of 225,310,000.[5]

The medium projection of this series extrapolated from 1960 on a straight line through 1975—five years to 1980—constitutes the United States population projection use in these crop pattern projections. Before these crop pattern projections were completed, however, a new series of United States projections was published.[6]

The "low" projection for 1975 in this new series gives a population for the United States of 198,632,000 which is higher than the medium projection actually used as indicated above. The projection presented in Table 1, however, has been retained as the basis of these studies, believing that the results obtained are thus reasonably conservative. Furthermore, it is believed that *there is as much danger today in believing that the high birth rates of recent years will continue unabated as there was in 1930 of believing, as many population experts did, that the low fertility rates of that period would be continued.*

California Population Growth—Historical and Projected Trends

The choice of the method used herein for projecting the California population has been based upon the belief that highly precise and involved methods of analysis are impractical because of the large likelihood of error involved in estimating the many different elements usually comprising highly involved population studies.

There are many other methods, of course, by which California population growth has been projected into the future. Most notable among these various projections is that of Helen L. White and Jacob S. Siegel of the United States Bureau of the Census published in 1952.[7] This projection which employs a so-called "ratio" method gives low, medium, and high projections for 1960 of 13,380,000, 14,017,000, and 14,919,000, respectively. Even the highest of these projections is lower than the one presented in Table 2 of this report.

The projection presented in Table 2 and in Figure 1C, however, has been designed especially for the peculiar characteristics of California population growth involving as it does a highly variable immigration rate and a more rapid rate of total population growth than that of any of the other states. In comparison with the White-Siegel projection mentioned above, it projects for 1960 a "reasonable lower limit" of California population of 15,065,000 and for 1980 of 21,300,000. California population in 1950, according to the census enumeration, was 10,586,000. This was an increase of 53.3 per cent over the corresponding figure in the 1940 census of 6,907,000. Two thirds of the increase from 1940-1950 was by immigration of persons

[4] The President's Water Resources Policy Commission. "A Water Policy for the American People," vol. I, Washington, U. S. Govt. Print. Off., 1950, p. 156, footnote 1.

[5] Hagood, Margaret Harmon, and Jacob Siegel. "Projections of the Regional Population of the United States in 1975." Agricultural Economics Research, vol. III, no. 2, April, 1951.

[6] U. S. Bureau of the Census. "Illustrative Projections of the Population United States by Age and Sex: 1955-1975." *Current Population Reports, Population Estimates.* Series P-25, no. 78. Washington, U. S. Govt. Print. Off., August 21, 1953.

[7] U. S. Bureau of the Census. "Projections of the Population by States: 1955 and 1960." *Current Population Reports, Population Estimates.* Series P-25, no. 56. Washington, U. S. Govt. Print. Off., January 27, 1952.

TABLE 2
CALIFORNIA POPULATION RATE OF INCREASE

Decade	Population, end of decade		Increase during decade			
	As enumerated	Trend	As enumerated	Trend	As enumerated	Trend
	1	2	3	4	5	6
	thousands				percent	
1850-1860	380	290	----	----	----	----
1860-1870	560	580	180	290	47.4	100
1870-1880	865	840	260	260	54.5	44
1880-1890	1,213	1,190	348	350	40.2	42
1890-1900	1,485	1,700	272	510	22.4	43
1900-1910	2,378	2,480	893	780	60.1	46
1910-1920	3,427	3,650	1,049	1,170	44.1	47
1920-1930	5,677	5,330	2,250	1,680	65.6	46
1930-1940	6,907	7,620	1,230	2,290	21.7	43
1940-1950	10,586	10,590	3,679	2,970	53.3	39
	Projection					
1950-1960	15,057	14,090	4,471	3,500	42.2	33
1960-1970	17,744	17,750	2,687	3,660	17.8	26
1970-1980	21,294	21,300	3,550	3,550	20.0	20

SOURCES:
Col. 1: 1890-1950. U. S. Bureau of the Census. Statistical Abstract of the United States, 1951. Washington, U. S. Govt. Print. Off., p. 31. (Table 38)
1960-1980. Projected—"reasonable lower limit."
Col. 2: Trend fitted to population as enumerated.
Cols. 3 and 4: Items in these columns are the differences between the successive items of columns 1 and 2, respectively.
Col. 5: Increase in population as enumerated for any decade expressed as a percentage of the population enumerated at the beginning of that decade.
Col. 6: Increase in population trend for any decade expressed as a percentage of the population trend at the beginning of that decade.

who in 1950 were 10 years of age and older. One third was natural increase and immigration of children who in 1950 were under 10 years of age. Thus, immigration is seen to be the most important element of growth in California's population. Immigration is a highly variable factor. In the decade ending in 1950, nearly 2,500,000 persons immigrated to California. The previous decade less than 1,000,000 came. In the post-World War I years, 1920-1930, 1,750,000 immigrated to California, whereas during the decade previous to that only a little more than 750,000 were included in the estimated immigration. These highly variable figures of immigration emphasize the precarious nature of population projections especially for a state that is growing as rapidly as is California.

The projection of Table 2, illustrated in Figure 1C, is one of four which have been made for California. Historical numbers of population of California at the end of each decade are shown from 1930-1950, inclusive, together with projections to 1980. California population was projected on the basis of assumptions of four rates of immigration. The projection presented in Table 2 has been selected from the above four projections for use in projecting the California crop pattern because the assumptions of immigration for this projection seem to be the most reasonable among those used. These assumptions are stated below in the discussion of *net effective immigration.*

Although no attempt has been made to project minor variations in population from year to year or deviations from the normal at any census period, the extreme variation during the decade 1930-1940 and again in 1940-1950 will undoubtedly be reflected in a major way at the turn of the next generation. The projection presented in Table 2 and Figure 1C accordingly contains adjusted immigration figures based upon expected economic effects of important changes in the age distribution of both California and the United States.

The major elements in the method of population projection that has been used in the current studies may be enumerated as follows:

1. Survivors of the population 10 years of age and over at the end of each decade who were living in California at the beginning of the decade.
2. Net effective immigration.
3. Child population under 10 years of age living in California at the end of each decade.

The sum of these three elements constitutes the total population in the state at the end of any given decade.

The use of the above elements has been dictated by the availability of information and the form in which it is available. The methods by which each of these elements has been estimated historically and projected were presented in detail in a publication by the State Division of Water Resources, issued in 1930.[8] Extension of these earlier estimates up to 1950 with revised projections to 1980 has been made in connection with the current studies.

Survivors at the End of a Decade. The survivors at the end of a decade of those of the population who were living in California at the beginning of the decade are all 10 years of age and older. Some of them are living in California while others have moved away. Those who have moved away represent a very small part of the total of the survivors. Separation of estimates of that portion of the survivors who have emigrated from estimates of those who have remained is very difficult. Therefore, estimates of the number of survivors at the end of the decade of those who were living in California at the beginning of the decade contain an unknown but small percentage of the total who have emigrated. This over-estimation is compensated for in the next step.

Net Effective Immigration. Net effective immigration during any decade, as used here, is equal

[8] Weeks, David. "Permissible Economic Rates of Irrigation Development in California." State Department of Public Works, Publications of the Division of Water Resources, 1930. (Bul. 35)

to the difference between the California population 10 years and older at the end of that decade and the number of survivors of the total population living in California at the beginning of that decade. It is short of being what is implied in the term *net effective immigration* by an amount equal to the survivors of the population living in California at the beginning of the decade and who have emigrated during the decade. The amount of this shortage is exactly equal to the excess indicated above in estimates of the number of survivors. This excess is the number of survivors of those who were living in California at the beginning of the decade and have moved away.

The sum of the number of survivors at the end of the decade of those who were living in California at the beginning of the decade, plus the California net effective immigration as defined here, represents the population 10 years of age and older at the end of a decade. Thus, the deficiencies in the numbers of survivors at the end of the decade and the excess in the net effective immigration, each equal to the survivors who have emigrated, exactly compensate each other. Because of this compensation and the fact that the emigration from California is small compared with immigration, *net effective immigration* as here calculated and projected becomes a useful though not an absolute measure of net immigration.

Projections of net effective immigration to California have been made on the assumption that it is closely related to the increase in United States population. Of course, it is also related to economic conditions in the state of origin and opportunities for a means of livelihood in California. In the absence of more satisfactory measures of these respective economic opportunities, which are both undoubtedly reflected in historical trends of immigration, projections of net effective immigration have been made on the basis of 4 different assumptions of the ratio of net effective immigration to projected increase in United States population 10 years of age and over.

The projected ratio of net effective immigration to projected increase in United States population 10 years of age and over which has constituted a basic assumption of the projection of California population presented in Table 2 is more than a graphical extrapolation of the historical trend of this ratio. This assumption is that the high ratio, 22.8 per cent, the actual rate during the decade 1940-1950, will have declined to 18.7 per cent in the decade 1950-1960 and to 13.4 per cent in the decade 1960-1970 but will rebound to 16 per cent in the decade 1970-1980. This change in the direction of trend of this ratio is based upon an opinion that the upsurge in the number of births expected in the decade 1970-1980 will react upon the economic situation to the extent that the rate of immigration will be stimulated. The expected upsurge in the decade mentioned would result from the fact that, early in the decade 1970-1980, the survivors of the 14,500,000 female children under 10 years of age in the 1950 United States population will have reached the ages of maximum fecundity. This age group in the 1950 population is 35 per cent greater than the group 10-19 years of age in the same population. After allowing for mortality, this group is now and will continue to be of great importance as it moves through the different phases of its growth. Thus, it will be in the late 1960's and early 1970's when the present "upsurge" in population which began in the 1940's will again make itself felt as another upsurge in the next generation. These considerations have made it seem necessary to depart somewhat from the smooth trend which would have resulted from a purely geometrical extrapolation.

Projection of the Child Population. As indicated above, the child population under 10 years of age living in California at the end of each decade is the third and last element entering into the projected California population. This child population under 10 years of age represents those who (a) have immigrated during a specific decade and (b) were born in California.

In either case their number reflects changes in fertility rates and, to some extent, survival rates. The use of this kind of an element which is equivalent to a crude birth rate is justified, as indicated above, by the high likelihod of error in the immigration rate. The use of highly refined birth rates would be inconsistent with the necessarily rough projection of immigration rates. The total child population has been projected indirectly in the ratio of the population 10 years of age and over to total population. This ratio has been projected to 1980 on the basis of an assumption of a slightly declining crude birth rate, notwithstanding the expected upsurge in the number of births indicated above.

Population and the Crop Pattern

The total acreage of California field crops irrigated has shown a close relationship in its expansion to the rate of increase of California population. This is a logical consequence of the expanding livestock markets on the Pacific Coast and of the recently demonstrated advantages of California compared with competing areas in the production of irrigated field crops. The close relationship observed over many decades between the rate of increase of the California irrigated field crop acreage and the rate of increase of California population growth suggests the projected rate of increase of the California population as the best indicator of the future rate of increase of the total irrigated field crop acreage.

California commercial truck crops, on the other hand, have a nationwide market, and for more than 20 years the rate of increase of their acreage has closely paralleled the rate of increase of the United States population. The acreage of these crops as a whole, therefore, most of which are irrigated, should be expected to increase at the projected rate of increase of the United States population.

The market for California orchard and vineyard crops also is largely nationwide, and to some extent the products of orchards and vineyards enter world trade channels. It would be expected, therefore, that the rate of increase of the total acreage of orchards and vineyards combined would approximate the rate of increase of United States population more closely than it would approximate the rate of increase of California population. The historical record of the orchard and vineyard acreage of California, however, does not conform to this expectation. An indirect method of projection based upon United States population growth rates and orchard and vineyard crop production has been applied and described at a later point.

Consequences of Under- or Overestimates of Future Population

Although it will be observed that the percentage distribution of the different crops within the California crop pattern is expected to go through a gradual change during the coming decades, the change is not so rapid as to create great concern over the consequences of error in judgment in the projection of the rate of population growth. The projections which have been made to 1980 in the present use of population growth rates constitute a preliminary assumption only, on the basis of which the nature of changes in the crop pattern can be observed. If the population projection for 1980, therefore, should not be attained until 1990 or 2000, the changes in the relative proportions of the projected crop patterns accompanying such an extension of time for the attainment of a given population would not materially change the relative proportion of the different types of crops within the pattern. Thus, as was stated at the outset, high precision in population projection is not essential for obtaining a fairly reasonable apportionment of the different acreages of crops within the total.

CALIFORNIA CROP PATTERN OF THE LATE 1940's

As previously stated, the California crop pattern for 1946-1950 constitutes the starting point from which projections have been made. Also, it has been stated that three major sources of information have constituted the basis upon which trends of acreage of different groups of crops have been extended into the future.

A Major Part As Indicator of the Whole

The 1946-1950 crop pattern, insofar as it is capable of description by information from all 3 of the above sources, is presented in Table 3. In view of the gaps and limitations mentioned earlier, projections have been made on the basis of historical analyses of a major portion but not all of the crop acreages shown in Table 3. It has been assumed that the percentage rates of increase estimated for this incomplete total may be applied to the entire acreage for projection by a close examination of Table 3. The first part of the table provides acreage statistics for 3 major groups of California crops: orchard and vineyard, commercial truck crops including potatoes, and field crops. It will be noticed that the orchard and vineyard acreage is subdivided into 4 subgroups: deciduous tree fruits, vineyard, citrus and miscellaneous subtropical fruits, and nuts. It also will be noticed that the field crops are further subdivided into major field crops (Group I) and miscellaneous field crops (Group II). The total acreages irrigated and nonirrigated as reported by the census for 1949 and by the Crop Reporting Service as a 1946-1949 average are 7,948,-000 and 8,398,000, respectively. In general, these acreages represent the average degree of undernumeration by the census when measured by the estimates of the Crop Reporting Service. It must be observed, however, that the time periods of these 2 figures are not exactly the same. Both of these estimates, moreover, do not include a number of additional crops which are reported on a noncomparable basis. On the other hand, a certain amount of duplicated acreage is included, representing interplanting and double cropping, making possible the harvest of more than 1 crop from the same land in a given year. The 1950 census made an attempt at elimination of this duplicated acreage in the reporting of summaries of cropland harvested. Census reports, after deducting duplicated acreage, give a total acreage of cropland harvested for 1949 of 7,957,000 acres, representing 57.8 per cent of the total cropland area of 13,765,000 as estimated by the 1950 census for the year 1949.

Irrigated Acreages

Historical trends in the acreages of irrigated California crops projected to an assumed stage of full development provide percentage increases to be applied to the irrigated acreages of the 1946-1950 crop pattern.

Percentages Irrigated. Table 3, in addition to showing acreages and irrigated acreages, indicates also the percentages irrigated for the different groups of crops including bearing and nonbearing acreages combined of the orchard and vineyard crops. Of the total cropland harvested, including duplicated acreage and excluding a small acreage of noncomparable items, 65.3 per cent was irrigated in 1949 according to 1950 census acreages irrigated and total. Of the total orchard and vineyard acreage, 78.6 per cent was irrigated in 1949.

For observing historical trends, however, information on bearing acreages is more complete. The percentages irrigated of the bearing acreages of orchard and vineyard and harvested acreages of other California crops, as calculated from the census acreages, total and irrigated, and presented in Table 4, have been applied to the acreages of crops harvested reported by the Crop Reporting Service for the purpose of obtaining an approximate estimate of the trend in irrigated acreage of individual crops and

TABLE 3

CALIFORNIA CROP ACREAGES, 1949, TOTAL AND IRRIGATED

Crop and crop group	Total acreage		Irrigated acreage		Percentage irrigated	
	Census, 1949	Crop Reporting Service, 1946-1949	Census, 1949	Division of Water Resources Survey	Census, 1949	Division of Water Resources Survey and California Crop Reporting Service
	1	2	3	4	5	6
	thousands of acres					
Orchard and vineyard						
Deciduous tree fruits [a]	428	471	288	482	67.4	----
Vineyard	489	544	393	485	80.4	89.2
Nut crops [b]	223	238	145	128	64.8	53.8
Citrus and miscellaneous subtropical fruits [c]	331	337	331	371	100.0	----
Subtotal	1,471	1,590	1,157	1,466	78.6	92.2
Commercial truck crops including potatoes						
Potatoes	100	112	96	----	96.0 [d]	----
Sweet potatoes	9	11	9	----	100.0 [d]	----
Other vegetables (except green beans) [e]	517	596	512	----	99.0 [d]	----
Subtotal	626	719	617	697	98.6 [d]	96.9
Field crops						
Major field crops (Group I)						
Alfalfa	893	974	817	974	91.6	100.0
Cotton	862	655	862	674	100.0	100.0
Rice	304	266	304	295	100.0	----
Total, Group I	2,059	1,895	1,983	1,943	96.3	----
Miscellaneous field crops (Group II)						
Beans (green and dry)	347	359	259	----	74.6 [d]	----
Sugar beets	128	146	128	----	100.0	----
Miscellaneous intensive field crops [f]	251	323	214	----	85.3 [d]	----
Small grains [g]	2,273	2,410	626	----	27.5	----
Extensive hay crops [h]	793	956	208	----	26.2	----
Total, Group II	3,792	4,194	1,435	1,814	37.8	43.3
Subtotal	5,851	6,089	3,418	3,757	58.4	61.7
TOTAL CROPLAND HARVESTED INCLUDING DUPLICATED ACREAGE	7,948	8,398	5,192	5,920	65.3	70.5
Noncomparable items						
Berries and other small fruits harvested for sale [j]	5	5	5	----	100.0	----
Nurseries and greenhouse products [k]	30	----	30	----	100.0	----
Other field crops [l]	215	103	---- [m]	----	----	----
Subtotal	250	108	35	----	----	----
TOTAL CROPLAND HARVESTED INCLUDING DUPLICATED ACREAGE AND NONCOMPARABLE ITEMS	8,198	8,505	5,227	----	63.8	----
Cropland exclusive of duplicated area [n]						
Cropland harvested (excluding duplicated acreage)	7,957	----	5,309	----	66.7	----
Cropland not harvested and not pastured	2,278	----	151	----	0.1	----
Cropland used only for pasture	3,530	----	----	----	----	----
Irrigated pasture	----	----	978	1,027	----	100.0
TOTAL CROPLAND EXCLUSIVE OF DUPLICATED AREA	13,765	----	6,438	6,947	46.8	----

[a] Includes bearing and nonbearing apples, peaches, pears, apricots, cherries, figs, plums, prunes, olives, quinces, and nectarines.
[b] The following bearing and nonbearing nut trees are included in both Census and California Crop Reporting Service compilations: almonds, walnuts, chestnuts, filberts, hazelnuts, and pecans. Pistachios, tung nuts, and black walnuts are included in the Census acreage but were not available in California Crop Reporting Service.
[c] The following bearing and nonbearing citrus and subtropical fruit trees were included in both Census and California Crop Reporting Service compilations: oranges, lemons, grapefruits, pomegranates, limes, avocados, dates, and persimmons. Guavas, loquats, mangoes, citrons, kumquats, limequats, and tangelos were available in the Census only.
[d] In rounding acreages to thousands, the percentage irrigated has varied as follows from the percentages given in Work Table 4-F: potatoes, 96.2 to 96.0 per cent; sweet potatoes, 99.9 to 100.0 per cent; miscellaneous intensive field crops, 85.1 to 85.3 per cent; other vegetables (except green beans), 98.9 to 99.0 per cent; commercial truck crops (except green beans), 98.5 to 98.6 per cent; and beans (green and dry), 74.7 to 74.6 per cent.
[e] The following vegetables were common to both the Census and the California Crop Reporting Service: artichokes, asparagus, broccoli, cabbage, cantaloupes and miscellaneous melons, carrots, cauliflower, celery, cucumbers, garlic, honeydews, honeyballs, lettuce, onions, peppers, peas, spinach, watermelons, tomatoes, and strawberries. The vegetables noted above comprise 95.3 per cent of the total harvested vegetable acreage reported by the Crop Reporting Service and 93.4 per cent of the Census reported harvested acreage. The balance of the vegetable acreage was not specified by the Crop Reporting Service. The Census did enumerate other vegetables to include kale, watercress, turnip greens, Swiss chard, salsify, rutabagas, rhubarb, radishes, collards, table beets, sweet corn, eggplant, endive and escarole, horse-radish, okra, green onions and shallots, pumpkins, squash, turnips, Brussels sprouts, chayote, chicory, Chinese cabbage, dandelion greens, green cowpeas, mustard greens, parsley, and parsnips.
[f] Includes corn and sorghums harvested for grain, flax, and hops.
[g] Includes oats, barley, rye, and wheat threshed.
[h] Includes small grain hay, clover, timothy, clover and/or timothy mixed, all other tame hay except alfalfa, and wild hay.
[i] Duplicated acreages are considered to be due to double- and inter-cropping.
[j] Both the Census and the California Crop Reporting Service reported harvested acreages for the following bush berries: raspberries, boysenberries, youngberries, loganberries, and blackberries. In addition, currant and gooseberry acreages were reported by the Census. The California Crop Reporting Service began estimating commercially important bearing acreages of bush berries in 1948. For the purposes of this study, an average of the 1948 and 1949 reported acreages was used. See Work Table 3-I.
[k] This item noted in the Census only includes three groups: (1) nursery products including trees, shrubs, vines, ornamentals, etc.; (2) flowers and flowering plants grown for sale; (3) vegetables grown under glass, flower seeds, vegetable seeds, vegetable plants, bulbs, and mushrooms. These three groups comprised 29,868 acres of which approximately 377 acres were cultivated under glass; all were assumed to be irrigated.
[l] Harvested acreages for alfalfa seed, Ladino clover, alsike clover, Sudan grass seed, vetch seed, Austrian winter pea, mustard seed, and sunflower seed were reported by both the Census and the California Crop Reporting Service. The latter also distinguished purple vetch seed. See Table 3-J. In addition to the foregoing crops, the Census reported acreages for the following: dry field and seed peas harvested for peas, sorghums cut for forage, etc., corn hogged or grazed, mixture of small grains and other grains not specified, red clover, sweet clover, fescue, Bermuda, bird's-foot trefoil, broomgrass, canary grass seed, root and grain crops hogged or grazed, castor beans, fennel seed, fenugreek seed, gourds, hemp seed, melons harvested for feed, pumpkins harvested for feed, rape seed, root crops for feed, silage made from grass and hay, safflower, and all other field crops harvested.
[m] Total alfalfa seed acreage was reported by the Census at 61,647 acres of which 49,715 acres or 80.6 per cent were irrigated. Information on other field crops irrigated in this group was not available.
[n] Acreages shown in this group were compiled by the Census.

SOURCES:

Col. 1: Detailed tabulations, compilations, and sources of the data on orchard and vineyard crops are presented in Work Table 3-A and on commercial truck and field crops in Work Table 4-F. Strawberries (4,341 acres) are added to the 513,230 acres of commercial truck crops of Work Table 4-F and rounded.
Col. 2: See Work Tables 3-B and 3-C for detailed data on orchard and vineyard crops and Work Table 3-F for commercial truck and field crops.
Col. 3: See Work Table 3-A for method of estimating irrigated acreages of orchard and vineyard crops not available in 1950 Census. Commercial truck crops and field crops irrigated acreages are from the 1950 Census, County Table 5a, p. 109. See Work Table 4-F.
Col. 4: California Division of Water Resources Survey. See Work Table 3-H.
Col. 5: Derived by dividing column 3 by column 1.
Col. 6: Derived by dividing column 4 by column 2.

groups of crops during the past few decades. For 1949, these percentages do not differ greatly from those presented in Table 3 for the bearing and non-bearing acreages combined. As originally calculated in 1950 when these studies were initiated, the Census of Agriculture for 1949 was not available. Furthermore, since that time, the Crop Reporting Service has made a somewhat extensive revision of a large part of its statistics. Percentages irrigated as presented in Table 4 are the basis for recalculating annual percentages irrigated and acreages irrigated annually for application to the revised Crop Reporting Service annual statistics of total crops harvested.[9]

Irrigated Acreages of the Different Crop Groups. Figure 2A to 2L, inclusive, present total and irrigated acreages of the major crops and crop groups in the California crop pattern. These illustrations are based upon the application of the percentage irrigated of Table 4 to the bearing and harvested acreages of the different crop groups.

In most of these illustrations, it will be noticed that the margin between irrigated and total acreage harvested is narrowing. On the whole, California agriculture is becoming more and more dependent upon irrigation which accounts in large measure for the rapidly increasing yields of the various crops in recent decades. Even the small grains are showing an increasingly larger acreage irrigated.

It is the irrigated portion of Figures 2A to 2L, with the exception of commercial truck crops, that is the basis of further processing in the projections of the various crops and crop groups presented in the following pages.

[9] Since in 1949 when these studies were initiated the 1950 Census of Agriculture was not available, reliance had to be placed upon the Division of Water Resources survey for the irrigated area and the Crop Reporting Service statistics for total cropland harvested. It has subsequently been found that these two sources of data are not exactly comparable and, therefore, the percentages obtained by that means were not applied. In general, the percentages obtained thereby were probably too high as indicated by the few that are presented for comparison in Table 3. Those that are not presented could not be calculated because in some cases the irrigated acreage as reported by the Division of Water Resources was greater than the total acreage as reported by the Crop Reporting Service. On the other hand, it is believed that the percentages irrigated obtained from the use of census data probably are slightly too low because of the particular manner in which the irrigation schedule was made out and filled in 1950 covering the 1949 crop year. It is believed that some substantial areas of irrigated land were left out of the census enumeration, particularly those items pertaining to orchard and vineyard acreage. This omission probably was due to the fact that enumerators were instructed not to report irrigation of crops which were not "wholly" irrigated, thus, excluding the irrigated acreage of the crops in farms on which only part of the crop was irrigated. In discussing this omission, the Bureau of the Census has stated that the acreage omitted is undoubtedly small in most of the states. It can be assumed, therefore, that the percentages presented in Table 4 and used in the calculations of annual percentages irrigated and irrigated acreages are somewhat underestimated for the orchard and vineyard crops.

PROJECTION OF THE ORCHARD AND VINEYARD CROP ACREAGE

Projection of the orchard and vineyard crop acreage is made as indicated above on the basis of historical trends in production, together with rates of increase in United States population growth.

Basic Assumptions

The total and irrigated acreages of the orchard and vineyard crops of California have been steadily declining since 1929. This trend is shown in Figures 2A to 2D. Production trends, on the other hand, have been climbing upward at a slightly greater rate than that of the United States population increase, indicating a rapidly increasing yield per acre. It is clear, therefore, that the projection of the acreage of this

TABLE 4

BEARING AND HARVESTED ACREAGES OF CALIFORNIA CROPS[a] PERCENTAGE IRRIGATED, 1909-1949

Crop and crop group	Irrigated acreage as a percent of total acreage				
	1909	1919	1929	1939	1949
Orchard and vineyard					
Deciduous tree fruits[b]	-------	47.0	64.3	*63.5*	*66.8*
Vineyard	-------	47.8	77.4	*76.6*	*79.7*
Nut crops	-------	36.6	62.0	*61.0*	*64.3*
Citrus and miscellaneous subtropical fruits	-------	83.3	99.4	*100.0*	*100.0*
Subtotal	28.4	52.6	74.0	*75.2*	*78.6*
Commercial truck crops including potatoes					
Potatoes	45.0	46.9	73.4	95.5	96.2
Sweet potatoes	-------	76.8	92.6	93.4	99.9
Other vegetables (except green beans)	-------	51.8	83.8	-------	98.9
Subtotal	-------	51.2	83.1	-------	98.5
Field crops					
Major field crops (Group I)					
Alfalfa	75.7	77.5	90.5	93.8	91.6
Cotton	96.0	96.2	97.6	100.0	100.0
Rice	-------	100.0	97.9	100.0	100.0
Miscellaneous field crops (Group II)					
Beans (green and dry)[c]	7.2	31.5	57.2	62.6	74.7
Sugar beets	18.6	63.1	88.0	94.5	100.0
Miscellaneous intensive field crops[d]	46.1	47.5	69.2	87.1	85.1
Small grains[e]	5.7	12.2	18.1	22.6	27.5
Extensive hay crops[f]	14.4	21.0	22.7	29.5	26.2
Total Group II	11.2	19.3	26.9	39.8	37.8
Subtotal	17.8	30.5	44.5	45.4	58.4
Irrigated pasture	-------	-------	-------	100.0	100.0

[a] Estimates based on the U. S. Bureau of the Census. Census of Agriculture. (Percentages italicized for orchard and vineyard, 1939 and 1949 are indirect estimates.) See Work Tables 4-A to 4-F, inclusive.
[b] Includes apples, peaches, pears, apricots, cherries, plums, prunes, and olives. See Work Tables 4-A and 4-B.
[c] In the survey and compilation of crops, 1946-1949, by the State Division of Water Resources, dry and green beans were combined. Since the above percentages are an important factor in projecting the above crop survey, green beans are eliminated from the commercial truck crops and included with dry beans in field crops. See Work Table 4-F.
[d] Includes corn, sorghums, flax, and hops. See Work Table 4-G.
[e] Includes wheat, barley, oats, and rye. See Work Table 4-G.
[f] Includes grain hay, wild hay, and miscellaneous hay. See Work Table 4-G.

group of crops presents a most difficult problem. For reasons presented later, tentative projections have been made on the basis of the three following assumptions:

1. That the trend in the rate of increase of the future acreage of California orchards and vineyards combined will follow closely the rate of increase of production of these crops.

2. That the present rapidly increasing yields per acre are temporarily excessive and will be offset by aging of trees and vines, replacement by young orchards and vineyards, and expansion of orchards into less productive areas.

3. That the future trend in the rate of increase of production of California orchard and vineyard crops will follow that of the United States population increase.

Steps in the Procedure

Steps in the procedure of projecting the acreage of California orchard and vineyard crops were as follows:

1. Selection of the crops to be included in preliminary projections. These crops included eight deciduous fruits, all grapes, three citrus fruits, and two nut crops. Their average bearing and total acreages by crop groups for the period 1946-1949 are presented in Table 5. This table indicates that the bearing acreages of the crops represented in this preliminary projection were a large percentage of the groups represented by them.

2. Graphical analysis of histories of production, fitting, and preliminary projection of trends for the four crop subgroups.

3. Determination of percentage increases in the production by crop groups from the 1946-1949 average to 1980.

4. Application of these percentage increases to the irrigated acreages of the Division of Water Resources preliminary compilation.

TABLE 5

TOTAL AND BEARING ACREAGE OF CALIFORNIA ORCHARD AND VINEYARD CROPS, 1946-1949

Crop group	Average acreage, 1946-1949	
	Bearing	Total
Deciduous tree fruits		
Included in preliminary projections	394,946	438,694
Not included in preliminary projections	28,339	31,756
Subtotal	423,385	470,450
Vineyard		
Total included in preliminary projections	489,582	544,371
Citrus and miscellaneous subtropical fruits		
Included in preliminary projections	294,467	312,681
Not included in preliminary projections	19,524	24,348
Subtotal	313,991	337,029
Nut crops		
Included in preliminary projections	206,200	236,721
Not included in preliminary projections	1,238	1,356
Subtotal	207,438	237,897
TOTAL	1,434,396	1,589,747

SOURCE: Work Table 3-B.

Summary of Results

In Table 6 is presented a summary of the projected irrigated crop pattern of California on the basis of the assumption of full development of the irrigable areas. In the upper portion of this table is presented the projection for the orchard and vineyard crops. It is expected that the trend of the acreage of de-

TABLE 6

SUMMARY OF PROJECTED CROP PATTERN FOR ASSUMPTION OF INITIAL FULL DEVELOPMENT OF IRRIGABLE AREA OF CALIFORNIA

Crop and crop group	Crop pattern harvested acreage trend: 1946-1949	Crop pattern harvested acreage trend: 1980 projection	1980 projection as percent of 1946-1949	Division of Water Resources crop survey	Irrigated acreage	Percent of total
	1	2	3	4	5	6
	1,000 acres			1,000 acres		
Orchard and vineyard						
Deciduous tree fruits			125	482	600	4.4
Vineyard			162	485	790	5.7
Nut crops			152	128	190	1.4
Citrus and miscellaneous subtropical fruits			135	371	500	3.6
Subtotal			142	1,466	2,080	15.1
Commercial truck crops including potatoes	690	918	133	697	930	6.7
Field crops						
Major field crops (Group I)						
Alfalfa	935	1,702	182	974	1,770	12.9
Cotton	543	1,570	289	674	1,950	14.2
Rice	230	470	204	295	600	4.4
Miscellaneous field crops (Group II)						
Beans (green and dry)	255	380	149	272	410	3.0
Sugar beets	154	385	250	165	410	3.0
Miscellaneous intensive field crops	294	710	241	314	760	5.5
Small grains	635	1,606	253	677	1,710	12.4
Extensive hay crop	362	759	210	386	810	5.9
Total Group II	1,700	3,840	226	1,814	4,100	29.8
Subtotal	3,408	7,582	222	3,757	8,420	61.2
Irrigated pasture			226	1,027	2,320	16.9
Total			198	6,947	13,750	100.0

SOURCES:
Col. 1: Items in this column are the averages of the trend values for the four year period, 1946-1949, determined graphically in Figures 10-20, inclusive.
Col. 2: The 1980 trend values determined graphically in Figures 10-20, inclusive.
Col. 3: Orchard and vineyard items from Work Table 6-A. All other items obtained by dividing each item in column 2 by the corresponding item in column 1.
Col. 4: From Work Table 3-H. These are acreage estimates from the Division of Water Resources preliminary compilation.
Col. 5: Rounded acreages obtained by multiplying items in column 4 by percentages in column 3.
Col. 6: Each item in column 5 divided by its sum and multiplied by 100.

ciduous tree fruits will be roughly 25 per cent greater in 1980 than in the base period 1946-1949; that the trend of the acreage of vineyards will be 62 per cent greater; the trend of the acreage of nut crops, 52 per cent greater; and that of the citrus and miscellaneous subtropical fruits, 35 per cent greater. Taking the entire orchard and vineyard acreage together, it is estimated that the trend of the total acreage of orchard and vineyards in 1980 will be 42 per cent greater than it was in the above base period. This expectation would result in the 1,466,000 acres of irrigated orchard and vineyard of the Division of Water Resources crop survey, being extended to slightly more than 2,000,000 acres by 1980. This orchard and vineyard projected acreage would be 15.1 per cent of the total acreage of irrigated crops, projected tentatively for 1980, of 13,750,000.

Notes on the Method Employed

It will be noted that percentage rates of increase estimated by projecting the total production irrigated and unirrigated have been applied to total irrigated acreages bearing and nonbearing on the assumption that the rate of increase of the total acreage of orchard and vineyard crops will be at the same percentage rate of increase as total production. Justification of this assumption has been reserved for later discussion.

Percentage Rate of Increase in Production. In column 3 of Table 6 are the percentages which represent the ratio of 1980 production to the average production for 1946-1949, respectively. These ratios for production presented in column 3 of Table 6 are assumed to be the same as the corresponding ratios between the 1980 acreages of the respective orchard and vineyard crop groups to the average acreages of these crop groups during the period 1946-1949, inclusive. These ratios reflect the rates of increase in production derived from the graphical analysis of histories of production.

Graphical Analysis of Histories of Production. Histories of production of California deciduous tree fruits, grapes, nuts, and citrus fruits were compiled.

Graphical trends have been drawn for each of these four groups of production histories and are presented in Figures 3A to 3D inclusive. These graphical trends of production have been adjusted to a uniform percentage increase which has been extended to 1980 at the same rate of increase as the projected United States population. The historical and projected trends resulting from this graphical projection are presented in Tables 7, 8, 9, and 10, respectively. Their rates of increase are brought forward to Table 6 and there applied in the final step.

Histories of bearing acreages of California orchard and vineyard crops were compiled. These acreages have not been used directly in the calculated projections. They are an important guide to judgment, however, in all steps of the analysis.

TABLE 7

TREND AND RATE OF INCREASE OF PRODUCTION OF CALIFORNIA DECIDUOUS TREE FRUIT 1920-1950 WITH PROJECTIONS 1950-1980

Decade	Trend in production at end of decade	Increase in production trend at end of decade	
	thousands of tons		percent
1910-1920	1,220		
1920-1930	1,580	360	29.5
1930-1940	1,930	350	22.2
1940-1950	2,200	270	14.0
	Projections 1950-1980		
1950-1960	2,400	200	9.1
1960-1970	2,550	150	6.3
1970-1980	2,690	140	5.5

TABLE 8

TREND AND RATE OF INCREASE OF PRODUCTION OF CALIFORNIA GRAPES 1920-1950 WITH PROJECTIONS 1950-1980

Decade	Trend in production at end of decade	Increase in production trend at end of decade	
	thousands of tons		percent
1910-1920	1,250		
1920-1930	1,800	550	44.0
1930-1940	2,320	520	28.9
1940-1950	2,850	530	22.8
	Projections 1950-1980		
1950-1960	3,350	500	17.5
1960-1970	3,850	500	14.9
1970-1980	4,380	530	13.8

TABLE 9

TREND AND RATE OF INCREASE OF PRODUCTION OF CALIFORNIA CITRUS FRUIT 1910-1950 WITH PROJECTIONS 1950-1980

Decade	Trend in production at end of decade	Increase in production trend at end of decade	
	thousands of tons		percent
1900-1910	450		
1910-1920	850	400	88.9
1920-1930	1,380	530	62.4
1930-1940	1,880	500	36.2
1940-1950	2,220	340	18.1
	Projections 1950-1980		
1950-1960	2,490	270	12.2
1960-1970	2,700	210	8.4
1970-1980	2,900	200	7.4

TABLE 10

TREND AND RATE OF INCREASE OF PRODUCTION OF CALIFORNIA NUT CROPS 1910-1950 WITH PROJECTIONS 1950 TO 1980

Decade	Trend in production at end of decade	Increase in production trend at end of decade	
	thousands of tons		percent
1900-1910	11.4		
1910-1920	28.1	16.7	146.5
1920-1930	49.4	21.3	75.8
1930-1940	72.8	23.4	47.4
1940-1950	94.6	21.8	29.9
	Projections 1950-1980		
1950-1960	112.0	17.4	18.4
1960-1970	126.6	14.6	13.0
1970-1980	137.1	10.5	8.3

PROJECTION OF THE COMMERCIAL TRUCK CROP AND POTATO ACREAGE

Projection of the acreage of commercial truck crops and potatoes presents two major difficulties. The first of these difficulties arises from the fact that truck crops more than almost any other irrigated crops are produced at the rate of one, two, or sometimes three crops from the same acreage in the same year. Furthermore, some truck crops are developed as interplanted acreages within orchards. The second difficulty is that complete irrigated acreages of truck crops are not provided by the 1940 and 1950 censuses from which calculations of percentage irrigated have been made.

Basic Assumptions

Assumptions made as a basis of projecting the commercial truck crop and potato irrigated acreage are as follows:

1. As indicated earlier, the trends of these acreages which are presented graphically in Figure 4A are expected to increase to 1980 at the same rate of increase as that of the United States population projection increase.
2. Notwithstanding gaps in the censuses of 1940 and 1950 from earlier observations and from more complete information on irrigated acreages, such as that provided by the 1930 census, together with such information as is available from the 1950 census, we are able to draw the conclusion that a very large percentage of the commercial truck crop acreage is irrigated, and we can also make the assumption that by 1980, for all practical purposes, all of the truck crop acreages will be irrigated.
3. Another assumption that must be made is that the actual net acreage of commercial truck crops will increase at the same rate that the harvested crop acreage increases, including all duplication. The latter acreage is all that we have to guide us in making the projection. It is considerably greater than the actual acreage used in producing truck crops.

Steps in the Procedure

The procedure followed in the projection of the commercial truck crop acreage may be indicated by two steps as follows:

1. Preliminary projection of trends in harvested acreage for the purpose of determining the percentage increase in harvested acreage from the average 1946-1949 to 1980. This step is shown in Table 11 and Figure 4A. It is based upon historical data.
2. Application of the percentage increase obtained in step 1 to the actual irrigated acreage of commercial truck crops (including potatoes) of the Division of Water Resources compilation. Step 2 is carried out and the results presented in Table 6.

Results of the Projection

As presented in Table 6, the expected rate of increase of the trend in the acreage of commercial truck crops, having been projected at the same rate of growth as the United States population, is expected to expand from approximately 690,000 acres in the 1946-1949 base period to an acreage of 918,000 acres in 1980 at which time it is expected that the entire acreage will be irrigated. Relative to other cropland uses, the commercial truck crop acreage in 1980 is expected to be approximately 6.7 per cent of the total acreage in irrigated crops.

TABLE 11

TREND AND RATE OF INCREASE OF COMMERCIAL TRUCK CROPS IN CALIFORNIA 1920-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1910-1920	223		
1920-1930	457	234	104.9
1930-1940	613	156	34.1
1940-1950	707	94	15.3
	Projections 1950-1980		
1950-1960	778	71	10.0
1960-1970	848	70	9.0
1970-1980	918	70	8.3

PROJECTION OF THE FIELD CROP ACREAGE

The irrigated acreage of California field crops has made a phenomenal expansion, extending over a number of decades. As stated previously, the acreage of the group as a whole has expanded at about the same rate as California population growth. While the total harvested acreage of field crops has made little change since 1910, the irrigated acreage has increased from less than 1,000,000 acres in 1910 to more than 4,000,000 acres in 1952.

Basic Assumptions

The basic assumptions upon which the irrigated field crop acreages have been projected are as follows:

1. It is assumed that the irrigated field crop acreages as a whole will continue to expand up to 1980 at the rate of California population growth.
2. It is assumed that individual field crops will expand at different and more or less unpredictable rates.
3. It is assumed that price control programs which may cause important deviations from the trend will not have permanent effects on the long-term trend.

Steps in the Procedure

The major steps in the procedure were as follows:

1. The trend in the harvested acreage of a major portion of all irrigated field crops was projected at the same rate of increase as that of the projected California population. This projection is

shown in Table 12 and in Figure 4B. It is based on historical data.

2. The trend acreage for 1980 of step 1 was expressed as a percentage of the average trend acreage of the base period 1946-1949 and recorded in column 3 of Table 6.

TABLE 12

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA FIELD CROPS 1910-1950 WITH PROJECTIONS FROM 1950-1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1900-1910	961		
1910-1920	1,345	384	40
1920-1930	1,896	551	41
1930-1940	2,712	816	43
1940-1950	3,770	1,058	39
	Projections 1950-1980		
1950-1960	5,014	1,244	33
1960-1970	6,318	1,304	26
1970-1980	7,582	1,264	20

3. The 1980 projected trend acreage recorded in column 5 of Table 6 was obtained by multiplying the percentage of step 2 by the irrigated field crop acreages of the Division of Water Resources compilation recorded in column 4 of Table 6.

4. Preliminary extrapolations of the historical irrigated acreage trends were made for eight individual field crops or subgroups of field crops. These extrapolations were made by a continuation of established historical trends to 1980. Subsequently, the 1980 extrapolated acreages were adjusted proportionately so their sum would equal the total projected irrigated field crop acreage trends as obtained in step 1. For each of these preliminary projections a table is presented showing the historical and projected trends. These are based on the historical crop data and irrigated acreages. These are Tables 13 to 21, inclusive. In addition, these projected trends are illustrated in Figures 4C to 4K, inclusive.

5. The 1980 projected trend acreages of step 4 were expressed as percentages of the corresponding average trend acreages for the base period 1946-1949 and recorded in column 3 of Table 6. When multiplied by the corresponding acreages in column 4, the projected acreages of column 5 were obtained.

Results of the Field Crop Irrigated Acreage Projections

Irrigated field crop trend acreages are projected as a group, according to Table 6, to a total of 8,420,000 in 1980 or at some period earlier or later at which this stage of expansion has been reached. It is expected that at that time field crops will constitute slightly more than 60 per cent of the entire irrigated acreage of the state.

TABLE 13

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA ALFALFA 1920-1950 WITH PROJECTIONS FROM 1950-1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1910-1920	570		
1920-1930	684	114	20.0
1930-1940	821	137	20.0
1940-1950	985	164	20.0
	Projections 1950-1980		
1950-1960	1,182	197	20.0
1960-1970	1,418	236	20.0
1970-1980	1,702	284	20.0

Major Field Crop Projection. The major field crops, from the standpoint of irrigation, are alfalfa, cotton, and rice. Projections of these major field crops are shown graphically in Figures 4C, 4D, and 4E and in Tables 13, 14, and 15, respectively. Calculations of irrigated acreages of these major field crops were based on historical data.

TABLE 14

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA COTTON 1910-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1900-1910	10		
1910-1920	75	65	650.0
1920-1930	185	110	146.7
1930-1940	360	175	94.6
1940-1950	620	260	72.2
	Projections 1950-1980		
1950-1960	950	330	53.2
1960-1970	1,305	355	37.4
1970-1980	1,570	265	20.3

TABLE 15

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA RICE 1910-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1900-1910	45	45	
1910-1920	105	60	133.3
1920-1930	175	70	66.7
1930-1940	250	75	42.9
1940-1950			
	Projections 1950–1980		
1950-1960	328	78	31.2
1960-1970	400	72	22.0
1970-1980	470	70	17.5

TABLE 16

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA MISCELLANEOUS FIELD CROPS 1920-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1910-1920	725		
1920-1930	1,008	283	39.0
1930-1940	1,383	375	37.2
1940-1950	1,840	457	33.0
	Projections 1950-1980		
1950-1960	2,392	552	30.0
1960-1970	3,050	658	27.5
1970-1980	3,840	790	25.9

TABLE 17

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA BEANS (GREEN & DRY) 1920-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1910-1920	105		
1920-1930	168	63	60.0
1930-1940	220	52	31.0
1940-1950	267	47	21.4
	Projections 1950-1980		
1950-1960	310	43	16.1
1960-1970	347	37	11.9
1970-1980	380	33	9.5

TABLE 18

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA SUGAR BEETS 1920-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1910-1920	41		
1920-1930	71	30	73.2
1930-1940	114	43	60.6
1940-1950	171	57	50.0
	Projections 1950-1980		
1950-1960	238	67	39.2
1960-1970	313	75	31.5
1970-1980	385	72	23.0

In Table 6 the projected acreage of alfalfa for 1980 is 1,770,000 acres compared with 974,000 acres during the base period 1946-1949.

Cotton is projected to a total acreage of 1,950,000 acres compared with 674,000 acres in the base period 1946-1949. The projected trend of the cotton acreage, although made prior to the 1954 acreage allotment under the Agricultural Adjustment Act, is surprisingly close to that allotment. But the 1953 trend acreage is far below the actual acreage harvested in 1953.

Rice has been projected to an acreage of 600,000 acres in 1980 compared with 295,000 acres in the base period 1946-1949. The rice acreage projected for 1980 will require the expansion to areas outside of the Sacramento Valley, the major rice-producing area of the state. Nevertheless, there are large areas of land in the San Joaquin Valley which are probably better adapted to rice production than they are to competing crops but where it will probably meet greater competition with other crops for the use of higher priced water.

These three major crops would constitute, under the conditions of projection, 12.9 per cent, 14.2 per cent, and 4.4 per cent, respectively, of the entire irrigated crop acreage. Their combined acreages at that time would amount to almost one third of the entire irrigated acreage of the state.

More about the economic implications of these extensions of acreage is presented in a later section of this report.

Miscellaneous Field Crop Projection. Beans and sugar beets which have been included in the miscel-

TABLE 19

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA MISCELLANEOUS INTENSIVE FIELD CROPS 1910-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1900-1910	63		
1910-1920	101	38	60.3
1920-1930	155	54	53.5
1930-1940	228	73	47.1
1940-1950	319	91	39.9
	Projections 1950-1980		
1950-1960	430	111	34.8
1960-1970	560	130	30.2
1970-1980	710	150	26.8

TABLE 20

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA SMALL GRAIN CROPS 1920-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1910-1920	247		
1920-1930	364	117	47.4
1930-1940	510	146	40.1
1940-1950	694	184	36.1
	Projections 1950-1980		
1950-1960	928	234	33.7
1960-1970	1,223	295	31.8
1970-1980	1,606	383	31.3

laneous field crop group might well have been included along with the major field crops. The irrigated acreage of beans, however, is considerably less than that of rice, although the total acreage exceeds rice. Although beans and sugar beets have been included within the miscellaneous field crops, they have been given special consideration in Figures 4G and 4H and in Tables 17 and 18 are presented the historical trends of their acreages and projections of these acreages to 1980. These are based on calculations of irrigated acreages.

In Table 6, percentage rates of increase of Tables 17 and 18 have been applied to the Division of Water Resources crop survey estimates for the base period 1946-1949 of 272,000 acres for beans and 165,000 acres for sugar beets, projecting each to 410,000 acres in 1980 at which time each would constitute 3 per cent of the total California irrigated acreage.

Miscellaneous field crops have been broken down further into other subgroups including miscellaneous intensive field crops, small grains, and extensive hay crops. Calculations were made of the irrigated acreage of each of these subgroups. Historical and projected acreage trends may be found in Tables 19, 20, and 21, respectively, while the projected acreage for 1980 in comparison with the base period acreage may be found in Table 6.

The projected irrigated acreage of the miscellaneous field crop group for 1980 is 4,100,000 acres compared with an average of 1,814,000 acres in the base period 1946-1949.

TABLE 21

TREND AND RATE OF INCREASE OF IRRIGATED HARVESTED ACREAGE OF CALIFORNIA EXTENSIVE HAY CROPS 1920-1950 WITH PROJECTIONS FROM 1950 TO 1980

Decade	Trend in acreage at end of decade	Increase in acreage trend at end of decade	
	thousands of acres		percent
1910-1920	231		
1920-1930	250	19	8.2
1930-1940	311	61	24.4
1940-1950	389	78	25.1
	Projections 1950-1980		
1950-1960	486	97	25.0
1960-1970	607	121	25.0
1970-1980	759	152	25.0

ECONOMIC IMPLICATIONS OF THE FOREGOING PROJECTIONS

An alternative approach to that applied in the preceding sections of this report could have been followed by making an economic analysis of each individual commodity involved. The intensity and detail of such an analysis could vary from occasional superficial observations to highly technical analyses of supply and demand factors with a full consideration of the relation of prices to production and acreage trends. Not only would such an alternative procedure involve an extreme amount of time, making an exhaustive study impossible, but, for a long-term analysis, measurement of the various elements which would be necessary in such a study probably would be quite impossible. For these reasons, resort has been made to the more rapid projection of the various elements on the basis of their past trends and projected population growth, modified where obviously needed or indicated by available information In this section on economic implications, therefore, it is proposed not to make an exhaustive economic analysis of all of the projections which have been presented but merely to call attention to certain outstanding considerations which have influenced decisions made in the process of projection. A tentative list of such considerations may be enumerated as follows: (1) price and demand analyses in long-term projections, (2) age distribution of the California orchard and vineyard crops in relation to future acreage requirements, (3) competition of the different crops for land and for water, (4) costs of water as a determinant of land use, and (5) price controls in relation to long-term land utilization trends. These and other considerations have been given careful thought in the appraisal of historical trends which in the foregoing projections have constituted, together with their relation to projected population growth, the major basis for estimating rates of growth.

Price and Demand Analysis in Long-Term Projections

Most of the price and demand studies of recent years have been for short-term outlook purposes. Only recently, notably in the studies leading to the report of the President's Materials Policy Commission in June 1952,[10] have price levels figured in an important way in long-term projection. To some extent, they are taken into account in the form of basic assumptions in connection with the report of the Hope Committee on a long-range agricultural policy presented to Congress in 1948.[11]

The methods used by the President's Materials Policy Commission in projecting the future demands on land productivity are indicated by the following quotation from its report:

> "In order to estimate the 1975 price of each major agriculture commodity which will be associated with the required production for that commodity in 1975 a series of supply-price equilibrium analyses have been made. In these analyses, . . . the probable prices are expressed in percentages of the projected 1975 parity prices. And . . . these probable prices are compared with those prevailing in mid-December 1951."[12]

The above quotation was the basis for "balancing the estimates of consumption against the estimates of potential output in order to determine the likely pattern of agriculture production in 1975."[13]

[10] Black, John D., Henry Lee, and Arthur Maass. "Future Demands on Land Productivity." *Resources for Freedom*, vol. V, pp. 63-75. Report to the President by The President's Materials Policy Commission, June, 1952 (Report 7). "The assumptions in this report are the same as those in vol. II, chapter 22, Projections of 1975 Materials Demand."

[11] U. S. Congress. House. Committee on Agriculture. *Long-Range Agricultural Policy*. A study of selected trends and factors relating to the long-range prospect for American agriculture. Washington, U. S. Govt. Print. Off., March 10, 1948, p. 17 (80th Congress, 2d Session).

[12] Black, Lee, and Maass, *op. cit.*, p. 73.

[13] *Ibid.*

An inquiry regarding detailed methods used in this type of projection disclosed the following:

1. "Within the framework of the assumptions given . . . by the Commission . . . first approximations [were made] of consumption requirements and productive capacity for 1975 using the best available data on technological change, resource inventory, consumption patterns and so on. . . .
2. "The production side was developed from many sources including the Land Grant College-B.A.E. estimates for 1955; material furnished by such agencies as the Bureau of Land Management, the Indian Service, the Soil Conservation Service, the P.M.A., the Forest Service, the state experiment stations, and also by many interviews and conferences with various agricultural scientists and research personnel from many parts of the U.S.D.A.
3. "When the first approximations of consumption and production for 1975 had been made, they were tested internally and then against each other for consistency so as to achieve a crude general equilibrium model. Adjustments or re-evaluation of the data was made where obvious inconsistencies came to light. This, of course, did not necessarily as a first approximation give a real 'equation' of demand and supply by commodity. It primarily pointed up what adjustments seemed to be necessary if a real balance was to be achieved in 1975.
4. "Between this point [the tests of consistency and construction of the crude equilibrium model] and the drawing up of the final equilibrium the report was circulated to a number of critics (Economists, Statisticians, and agricultural scientists) so that the final draft of the model bore the impact of criticism and advice from a large number of well qualified men. . . .
5. "The computation of the 'supply-price equilibrium analyses' . . . was far from a precise statistical process. The data necessary for such a computation technique is simply not available."[14]

In the Hope Committee report, although historical trends were made an important part of the projection, certain assumptions were made with respect to price levels and purchasing power under three sets of possible future conditions, one of which was considered to be "most likely in a situation characterized by relatively high employment over most of the years ahead with nonemployment occasionally running as high as 10 per cent."[15]

[14] Personal letter to David Weeks from James T. Bonnen, Graduate School of Public Administration, Harvard University, Cambridge, Massachusetts, November 26, 1952.

[15] U. S. Congress. House. Committee on Agriculture. *Loc. cit.*

Another study was made of the agricultural productive capacity of the United States attainable in 1955. This was accomplished by the integration of special studies made in the various states by committees working in collaboration with the members of the United States Department of Agriculture. In California the report of this committee was made in June, 1952, by Trimble R. Hedges and Warren R. Bailey.[16]

Distinction is made between the projections made herein and those made in 1951 for the year 1955 by the Joint Land-Grant College, Department of Agriculture, Committee on Appraisal of Agricultural Productive Capacity. That study was to determine "California's agricultural productive capacity" in 1955. It was based upon consumption of "high level economic activity, generally favorable farm prices, adequate supplies of production materials, but a somewhat smaller farm labor force." [17]

Although the results of that study were not available when the preliminary estimates of the crop pattern for water requirements were made, they have been useful in the complete recheck of those estimates made in 1953 prior to publication.

It must be borne in mind, however, that this water requirements study instead of attempting to project *productive capacity* for a short period has attempted to project a trend of *most likely* acreage of land use by groups of crops over a long period. Instead of being based upon an assumption of cost and income prices as was the case in the 1951 projection of 1955 productive capacity, the long-term projection was based upon a trend from which deviations above and below trend would be expected. Instead of being projected from a single point of time as was the productive capacity study, these crop pattern projections were based upon an analysis of historical trends and of indicators that might best indicate the future course of these historical trends.

Much effort has been made to appraise these different approaches to long-term projections of the agricultural crop pattern, and the conclusion has been reached that to make an assumption of price levels 30 years in the future involves so many uncertainties that possibility of error is increased by such methods rather than being diminished. All of these points of view, however, are highly valuable from the standpoint of aiding the judgment since price equilibrium is a part of the process of land use determination. It is believed, however, that the projected trends in the foregoing analysis have given due consideration of these economic forces without any attempt to separate them out from other factors causing variations in production and acreage. Other factors of dynamic character may be of even greater importance in the projection of land use trends.

Age Distribution of the California Orchard and Vineyard Crops in Relation to Future Acreage Requirements

The peculiar characteristics of California agriculture prevent the immediate response of supply to prices of agricultural commodities or, the reverse, the response of price to the estimation of the potential supply. This sluggishness in the operation of the forces of supply and demand is caused by the large acreage of California crops which is planted to perennials which require many years to come into full production after they are planted. The orchard and vineyard acreage of California was overexpanded in the years immediately following World War I. This overexpansion and the resulting depressed prices were followed by tree-and-vine-pulling programs which removed overaged trees and orchards and vineyards planted on unproductive lands, upsetting the age distribution which had been in the process of gradual readjustment since that time. In the second place, an increasing percentage of irrigated and maturing trees and vines has resulted in an abnormal increase in yields per acre. Gross tonnage, therefore, representing orchard and vineyard production, presents a much more rational basis of projection than acreage itself. California production of orchard and vineyard crops increased for several decades prior to 1950 at a slightly greater rate per decade than that of the United States population. This greater rate can be attributed to an increasing per-capita consumption of fruit in the United States, an increased consumption by an increasing California population having a high per-capita consumption, and by a tendency to overexpansion of orchard and vineyard crops because of delayed response of production to the demand of any particular time. This delay is caused by the time required to bring orchards and vineyards into production in response to a given demand. By the time the trees come into full bearing and the acreage in excess of that warranted by the demand has been planted, overexpansion has resulted. This type of situation, however, seems to have been reversed for the present and seems likely to continue during the next few decades.

At the close of 1952, California orchards and vineyards appeared to have passed their prime production age and were approaching a period in which further increase in production by maturing young orchards would be more than offset by declining production of aging trees, many of which would soon be replaced by nonbearing young orchards or other crops. In 1936, 69 per cent of the California orchard and vineyard acreage was comprised of trees and vines 22 years of age or younger, indicating a heavy

[16] Hedges, Trimble R. and Warren R. Bailey. *Appraisal of California Agriculture Productive Capacity Attainable in 1955.* Berkeley, 1952. 79p. (Calif. Agr. Exp. Sta. Mimeographed Report 130)
[17] *Ibid.*, Summary, p. i.

production potential for the remaining years of their economic life beyond 22 years. By 1952 this percentage had fallen to 42 per cent, indicating that 58 per cent of the acreage had now reached the end of its economic life or had passed into a period of declining yield.

California orchard and vineyard acreages are made up of some relatively short-lived crops, other crops having a medium economic life span and still other crops which have a long life span. The age at which it is more economical to remove an orchard or vineyard than to continue it in production varies because of many environmental conditions and according to the management under which such crops are operated. However, the orchard and vineyard area in California can be roughly grouped into the three above classes or groups according to the economic life span.

Peaches and apricots are short lived, having an economic life span as estimated by Professor R. L. Adams of 20-30 years. In 1936, 78 per cent of the peach and apricot acreage was comprised of trees and vines 22 years of age and under compared with 43 per cent in 1952. With respect to prunes which have a medium life span, the percentage in this age class of 22 years and younger decreased from 59 per cent in 1936 to 22 per cent in 1952.

The balance of the fruit crops is long lived, the length of life having been estimated by R. L. Adams at from 40-50 years. These longer lived fruits also show a marked decline in the younger age class. Apples declined from 43 per cent of the acreage 22 years and younger in 1936 to 29 per cent in 1952 and pears from 68 per cent to 23 per cent. Similarly, the vineyard acreage declined in its percentage age distribution in the 22-years-of-age-and-younger class from 70 per cent in 1936 to 44 per cent in 1952, nuts from 77 per cent in 1936 to 51 per cent in 1952, and citrus from 64 per cent in 1936 to 33 per cent in 1952. Even with these longer lived crops, the percentage in the younger age groups has declined markedly which is significant in relation to Figures 2C and 2D showing the marked decline in the acreage of deciduous tree fruits and vineyards, particularly deciduous tree fruits.

In this connection also, the trend in yields per acre shown in Table 22 is significant. Citrus yields in California increased from an average of 4.2 tons per bearing acre in the 4-year period 1920-1923 to 7.7 tons per bearing acre in the 5-year period 1945-1949. Grapes increased in yield from 4.4 tons per acre in the period 1919-1923 to 5.6 tons in the period 1945-1949. Deciduous tree fruits, excluding apples, increased from 3 tons in the period 1919-1923 to 5.2 tons in the period 1945-1949. Apples made an even more phenomenal increase in yield from 4.1 tons to 7.6 tons, respectively, in these 2 periods. These trends in yield reflect increased acreages irrigated, increased applications of fertilizer, other technological improvements in management, and removal of low production orchards and vineyards. However, probably the biggest element in this increasing trend of yield is represented above by the phenomenon characterized by the declining percentages in the younger age groups and the increasing average age of the orchards.

TABLE 22

YIELD PER BEARING ACRE OF ORCHARD AND VINEYARD CROPS

Calendar year of harvest	Citrus		Deciduous fruits: Vines		Deciduous fruits: Trees, excluding apples		Deciduous fruits: Apples	
	Cal.	U. S.	Cal.	U. S.	Cal.	U. S.	Cal.	U. S.
	short tons per bearing acre							
1919-1923	3.0	------	4.4	3.5	3.0	1.7	4.1	1.5
1920-1923	4.2	4.9	------	3.5	------	1.7	------	1.6
1924-1928	4.9	4.8	3.8	3.2	3.0	2.0	4.3	1.7
1929-1933	6.0	5.3	3.4	2.8	3.2	2.2	5.0	1.8
1934-1938	6.2	5.2	4.4	3.6	3.7	2.5	5.5	2.0
1935-1939	6.5	5.7	4.6	3.8	4.0	2.6	5.9	2.2
1940-1944	8.0	7.5	5.0	4.2	4.5	2.7	5.6	2.3
1945-1949	7.7	8.7	5.6	4.7	5.2	3.1	7.6	2.2

SOURCE: From data compiled from official sources by S. W. Shear, Giannini Foundation of Agricultural Economics, University of California.

Further increases in age, however, probably will have an opposite effect. During the recent decades, these orchards have been passing through their prime production period. Judgment regarding future trends in yield per acre and acreage requirement for the maintenance of either constant production or gradually increased production with the increase in demand requires careful consideration of this factor.

Competition of the Different Crops for Land and for Water

Hazards of Projecting a Single Crop. Although each of the major field crops has been considered by itself, it must be emphasized over and over again how great the hazard is of projecting individual crop acreages. The projected acreage of any single crop easily could be upset by a plant disease, crop acreage control, or by successful competition by other crops. The acreage changes of the last few years in cotton are illustrations of the likelihood of error in projecting the acreage of any individual crop which reflects year-to-year changes in economic conditions and of price-support measures. Alfalfa, cotton, and rice, therefore, each considered separately, may merely symbolize some substitute crop or crops which might suddenly or gradually replace a portion of the acreage. Annual crops as a group are more readily shifted in response to changes in price outlook. Long-run trends, however, do not attempt to foretell these annual variations. But long-term trends, also, may vary widely from expectations within a single crop agriculture. The projections for individual crops, therefore, in the foregoing pages are made merely as a basis of applying water requirement rates to specific acreages on the assumption that shifts in land utilization in unexpected directions may follow roughly the same general pattern of water requirement. Errors in the projection of the crop pattern, therefore, are likely to be much greater than errors in estimates of water requirements.

As precarious as the projection of the California crop pattern into the future may be, an error one way or another in the estimates made if the projection is used for the purpose intended should not prove to be a serious matter. If the acreage projection of a given crop should in later years turn out to be too low in comparison with actual acreages, some other crop with the same or slightly higher or lower water requirement undoubtedly will have taken its place. The total amount of the error of such a shift would be the difference between the water requirements of the crop projected and the substitute crop which took its place.

Grouping of Crops Reduces Hazard. Groups of crops may be projected with much greater certainty of the projected acreage being realized than individual crops because farmers are constantly on the lookout for crops which will bring them the greatest return. Shifts are constantly being made, particularly among the annual crops, in response to price changes. The economy of such shifts is complicated and requires more complete treatment than is possible here. Although prices serve as the inducement to change, they tend to become such that there will be a sufficient amount of each type of crop to supply the demand. In this competition by crops for a given area, that crop for which there is an active demand and which will suffer greatest increase in cost of production if produced elsewhere will gain in the competition for the given area. Thus, demand, the physical characteristics of the area, and technological factors determine the crop pattern. The demand for a given crop is quite variable from time to time. Technological changes are less abrupt. Yields of the field crops as shown in Table 23 reflect these technological changes and irrigaton development. The major change in physical character of an area is its water supply for irrigation. These dynamic changes cause individual crops to come and go, but changes in the general character of groups of crops are more gradual.

For the above reasons, projection of groups of crops is far safer than projection of individual crops. Thus, the projections in the foregoing pages for the crop groups are much more reliable than for the individual crops such as one of the major field crops: alfalfa, cotton, or rice.

Water Requirements in Relation to Crop Shifts. It will be noticed that the latter crop group covers such broad acreages or utilizes such large amounts of water that each individual crop falls within a group by itself. The major field crops as a whole are heavy users of water. A shift from alfalfa to irrigated pasture, economically a logical shift, would be a shift to another crop of high water requirements but to one having different soil requirements. Such a shift, therefore, probably would be an indirect one. Good alfalfa land has a deep soil, economically adaptable to many types of intensive deep-rooted crops. From an economic standpoint, however, there is a tendency to substitute for alfalfa the more cheaply harvested irrigated pasture which may be grown on a wide variety of shallow soil conditions. The great extent of such soils within the state would tend to bring about their utilization for this high water requirement crop to which they are limited in their adaptation so far as intensive irrigated agriculture is concerned. Such a shift, therefore, would take the form of alfalfa land

TABLE 23

AVERAGE YIELD PER HARVESTED ACRE OF SELECTED FIELD CROPS

Crop years[a]	Alfalfa	Cotton	Rice	Beans (dry)	Sugar beets	Wheat	Barley	Grain hay	Wild hay
	tons	pounds	bushels	pounds	tons	bushels		tons	
1910-1914	[b]	377.0	----------	951.2	9.8	15.3	24.7	[b]	1.1
1915-1919	[b]	290.8	59.9	968.2	9.0	15.3	26.8	[b]	1.1
1920-1924	3.6	237.6	52.4	807.2	8.8	17.2	25.9	1.3	1.0
1925-1929	3.6	368.8	55.7	1,033.2	9.5	18.2	27.3	1.4	1.2
1930-1934	3.9	493.4	68.7	1,165.8	13.6	17.7	25.6	1.3	1.0
1935-1939	4.3	582.4	70.6	1,243.6	13.7	19.3	27.5	1.5	1.2
1940-1944	4.3	586.4	64.7	1,274.0	15.8	17.4	27.5	1.6	1.3
1945-1949	4.5	610.2	67.6	1,337.4	17.5	18.1	30.6	1.4	1.4
1950	4.7	805.0	77.2	1,457.0	18.8	21.0	34.0	1.5	1.2
1951	4.6	640.0	75.6	1,495.0	18.9	17.0	30.0	1.4	1.2
1952[c]	4.7	622.0	80.0	1,463.0	18.0	21.0	36.0	1.6	1.4

[a] Five-year periods, 1910-1949; annual yields, 1950, 1951, and 1952.
[b] Not estimated separately from all tame hay prior to 1919.
[c] Preliminary estimate.

SOURCES:
U. S. Bureau of Agricultural Economics and California Bureau of Agricultural Statistics, California Crop and Livestock Reporting Service:
California Field Crops Statistics, 1866-1946. Sacramento, July, 1947. Processed.
California Field Crops Statistics, 1944-1952. Sacramento, May, 1953. Processed.

shifting to orchard and vineyard when the demand requires, and the feed formerly supplied by the alfalfa would be produced on shallower soils and rolling land adapted to pasture. Prior to the availability of water for extending the acreage of irrigated pasture, however, and prior to the need of the deeper soils for orchard and vineyard, the alfalfa acreage is likely to be extended into areas recently producing cotton.

A shift out of this group to either the orchard and vineyard classification or to the miscellaneous field crops would be a shift to a lower water requirement. Similarly, a shift either from the major field crops from orchard and vineyard to miscellaneous field crops in general is a shift from a higher to a lower water requirement with the exception possibly of sugar beets, the water requirements of which approximate those of orchard and vineyard. The miscellaneous field crop groups as a whole, however, are low water users. Shifts within such a group are not as significant from the standpoint of water requirements as shifts from one group to another. It is not a serious matter, therefore, if the individual items within such a group fall short or long in relation to the projected acreage.

There has been considerable discussion of whether land or water is the limiting factor in the determination of the California crop pattern. In other words, will the crop pattern reach its full development before the land available is exhausted because of limited water supplies or will the crop pattern reach its full development only when all of the irrigable land area is exhausted because of the scarcity of land and the greater abundance of water. Of these two possible situations, preliminary studies have progressed sufficiently far to indicate that availability of land will place the ultimate limit on the expansion of the irrigated area and that additional supplies of water will still be available after the available irrigable land area has been exhausted. Water as a limiting factor, however, may take the form of high costs of development and distribution of water even before the available sources have been exhausted. At each extension of the margin of irrigated area, therefore, demand must have been strengthened to the extent that prices may be sufficient to meet the increasing costs of water development.

Examples of the situations just described may be found in the competition of small grains and rice on the lands adaptable to both and again in the extension of irrigated agriculture to certain parts of the state for which water delivery will involve particularly high costs. In the first example, consider the competition between rice and wheat. Under present and past conditions, California wheat has been used largely for poultry and livestock feed. Varieties for use in the baking industry are not, on the whole, produced in California. Whether or not varieties for direct human consumption could be produced in the State would be a matter for further consideration by plant breeders and special economic studies. At any rate, it may be assumed that the price of wheat ultimately will increase as the growth of population in the Unted States continues to the point where wheat ceases to be an export commodity. When that point is reached, prices of wheat, even though there may be other than direct human uses, will rise to the point where energy values produced per acre would become an important consideration in its being maintained or expanded as an irrigated crop. Rice produces more energy units per acre than wheat. Wheat produces more energy units per acre-foot of water than rice. Table 24 presents comparative energy production per acre and per acre-foot of water in the interior valleys of California. Food energy per acre of irrigated wheat has been estimated at 2,588,000 calories and for rice at 4,233,000 calories, whereas the food energy produced per acre-foot of water has been estimated at 2,588,000 calories for wheat and only 705,000 calories for rice. The reason for this difference is due to the fact that only 1 acre-foot of water is estimated as being required to complete the maturity of wheat, whereas 6 acre-feet per acre are required for rice. The projected acreage for rice of 600,000 acres, as indicated in Table 6, therefore, may be attained in competition with small grains, the most likely substitute crop on the heavy soils adapted to rice because of the limited land area rather than because of the limitation of water supply.

TABLE 24

FOOD ENERGY YIELDS OF IRRIGATED WHEAT AND RICE IN THE SACRAMENTO VALLEY OF CALIFORNIA

Steps in the calculation of energy yields	Wheat	Rice
Step 1. Average yield per acre (pounds)	1,680	3,700
Step 2. Estimated percentage utilized as human food	80.0	69.0
Step 3. Average food energy yield per acre utilized as human food (pounds)	1,344	2,553
Step 4. Food energy per pound as purchased (calories)	1,523	1,644
Step 5. Food energy per acre (thousands of calories)	2,047	4,200
Step 6. Irrigation requirements per acre (feet)	0–1	5
Step 7. Food energy per acre-foot of water (thousands of calories)	2,047	840

SOURCES:
Step 1: State Department of Public Works, Division of Water Resources. "Irrigation Requirements of California Crops." Sacramento, California State Print. Off., 1945. Table 72, p. 123. (Bul. 51)
Step 2: The estimate of 80.0 per cent wheat utilized as human food was obtained from the Food Research Institute, Wheat Studies, vol. XVII, 1940-41, Stanford University Press, Stanford, California, 1941, pp. 278 and 285. The 69.0 per cent yield of milled rice from rough rice is taken from Morris B. Jacobs, The Chemistry and Technology of Food and Food Products, Interscience Publishers, Inc., New York, 1951, p. 2049.
Step 3: Step 2 x step 1.
Step 4: U. S. Department of Agriculture, "Composition of Foods," **Agriculture Handbook**, No. 8, pp. 82 and 89. Washington, D. C., June, 1950. Processed. (The caloric value of white wheat was used as soft white wheat varieties are grown almost exclusively in California.)
Step 5: Step 4 x step 3.
Step 6: Same as step 1.
Step 7: Step 5 divided by step 6.

In a situation where land is the limiting factor in the ultimate crop pattern under equal conditions of demand for energy in cereal crops, rice would tend to increase in price to the point that it would gain possession of any given area of competition. Even before the land supply is exhausted, however, the cost of water will have become so high that small grains may retain possession of the rice land potential area for an indefinite period of time. Furthermore, the small grains are an important supplementary crop in a rice area as a means of weed control.

Costs of Water as a Determinant of Land Use. In the consideration of the crop pattern in those parts of the state where costs of water delivery are expected to be very great, it may be assumed that a changing demand may create prices that will induce development of water supply for such areas. To forecast competitive conditions between crops for such an area in a remote period in the future is by far more hazardous than consideration of expansion within partially developed areas having more moderate water costs. A low yield of food energy per acre of land results when it produces livestock feed for the indirect production of meat or dairy products for human consumption. When the revised projections of United States population growth have been realized, energy requirements may have to be met by giving greater and greater consideration to cereal production as a source of energy. These considerations, as vague as they now are, have been given some thought in the extension of irrigated cereals and livestock feed crops.

Geographical Distribution of the Crop Pattern. It is necessary in its application to break down the foregoing projections into the estimates of the crop pattern for the different hydrographic areas of the state. What has just been said about the relation of water development costs in certain irrigated areas has a very important bearing upon geographical crop distribution. In general, the smaller the area, the more hazardous are the predictions for its future utilization. Suggested procedure in making the best possible geographical distribution, however, would be on the supposition that the ceiling of irrigation development in the area would be determined by the land classification of that area. Land classification thus will become an important element in the breakdown of the overall projection by areas. A brief summary of the general characteristics of the land classification available for such a purpose is quoted below.

"Approximately 12,000,000 gross acres of irrigable lands have been segregated into land classes by Bureau of Reclamation and Division of Water Resources surveys. Another 8,000,000 gross acres have been mapped as irrigable, but not segregated into land classes. Of the segregated land classes, over 7,300,000 acres are Classes 1 and 2, 3,500,000 acres are Class 3, and 1,000,000 acres are Class 4.

"Soil depth was not in all cases the limiting factor in determining Class 3 lands. In the Lahontan and Colorado Desert Areas, moisture-holding capacity was the limiting factor while in the San Joaquin Valley, salinity and alkalinity often determined the suitability. Approximately 50 per cent of the 4(2) and 4(3) and all of the Class 4P lands were assumed to be suited only for shallow-rooted crops.

"For the unsegregated irrigable lands the estimate was based upon a broad general knowledge of the lands and soils. In the metropolitan areas it was assumed that shallow irrigable lands will be absorbed by urbanization, and that those not so absorbed will be deep and of the highest quality."[18]

A rough estimate of lands in California suited only for shallow-rooted crops is presented in Table 25.

TABLE 25

ACREAGE OF IRRIGABLE LANDS IN CALIFORNIA SUITED ONLY FOR SHALLOW-ROOTED CROPS

Major hydrographic divisions	Acres
1. North Coastal area	250,000
2. San Francisco Bay area	-------
3. Central Coastal area	350,000
4. South Coastal area	400,000
5. Central Valley area	
Sacramento Valley	1,250,000
San Joaquin Valley	1,500,000
6. Lahonton area	150,000
7. Colorado Desert area	200,000
TOTAL	4,100,000

SOURCE:
California Division of Water Resources. Unpublished material, July 17, 1952.

Price Controls in Relation to Long-Term Acreage Trends

Most of the great volume of discussion concerning farm price control policy has generally avoided the difficult question of their probable effects upon long-term acreage trends. An appraisal of the foregoing projections in the light of price controls may be necessary. It will be difficult for many to reconcile the huge surpluses of stored crops still in the hands of the Commodity Credit Corporation with the rapidly rising trends in acreage projected above for some of the California crops.

Price stabilization has been sought through the use of several devices. Among the more important of these devices may be enumerated the following: (1) payments or grants-in-aid to farmers, (2) nonrecourse loans, (3) acreage allotments, (4) marketing quotas (domestic and international), (5) establishment of a scale of prices for or a set of regulations of the

[18] Personal letter to David Weeks from William L. Berry, State Department of Public Works, Sacramento, California, July 17, 1952.

movement of different classes of the commodity (market agreement and order programs), and (6) tariffs.

In addition to the above devices are the various marketing activities carried on under the broad powers granted the Commodity Credit Corporation including various types and forms of subsidy payments, multiple price systems, commodity diversions, etc.

Some of the above measures tend to expand the acreage devoted to the production of the affected commodities while others tend to contract acreage. Recent legislation has sought combinations of devices for optimum regulation of acreage, production, price, and income. The complex problems, however, of competition between crops for the use of the land and between different areas for the different crops have not been solved. A definition and brief description of the different control devices follow.

Payments or Grants-in-Aid to Farmers. Payments directly to farmers are made in the interests of conservation and with a view to insuring to the farmer a just share of the national production required for domestic consumption and for export. Such payments are made (1) for the performance of farm practices that are presumed to restore soil productivity and prevent erosion, (2) to change the use of land in the interests of soil conservation and as a means of indirect income stabilization, and (3) as payments in direct support of farm prices and income.

In recent years the payments made for farm practices and for changes in land utilization have become more truly a conservation program. They had been introduced originally to avoid the legal difficulties of acreage reduction as a means of price control. They have lost much of their earlier significance, however, in carrying out the price stabilization policy stated and implied in the Soil Conservation and Domestic Allotment Act. "Payments or Grants-in-Aid" directly to farmers currently remain the major means of effectuating the Agricultural Conservation Program of the Production and Marketing Administration. Although the existing price-support legislation still provides for price-support payments, other devices have in general taken the place of such payments in the broader objective of price support. "Conditional Payments" directly to farmers, however, still constitute an important feature of the Sugar Act of 1948.

Nonrecourse Loans. In lieu of payments for performance and of direct purchase of commodities from the producer, the Commodity Credit Corporation is empowered to make loans to the producer on stored and sealed commodities as collateral. Sale of the collateral, even at a price below the amount of the loan by the Corporation for the repayment of the loan, does not obligate the producer to make up the loss. On the other hand, if the price rises above the value of the loan, it can be paid and the producer may receive the higher market price for his product. The loan thus becomes a means of price support for "basic" commodities, for designated nonbasic commodities, and, if certain criteria are fulfilled, for other "nonbasic" commodities. Basic commodities of importance to California are wheat, cotton, and rice. Nonbasic commodities of importance to California include wool, Irish potatoes, and certain dairy products. Sugar beets are covered by the special Sugar Act of 1948.

Acreage Allotments

An acreage allotment is an acreage determined in advance as that required to produce the annual supply necessary for the national domestic consumption and export of a given commodity and adopted by those in administrative responsibility as a basis of allocation among the states, counties, and farms. The criteria for making these allocations have varied from time to time according to the commodity and the particular act under which the allotment has been administered. Enforcement usually is by means of a price penalty for violation of the allotment.

Acreage allotments have been a part of the Soil Conservation and Domestic Allotment Act and of the Agricultural Adjustment Act of 1938. Their use has been broadened by the Agricultural Act of 1949. They have been introduced with the view to serving two purposes in general: (1) as a direct means of maintaining an adequate supply of agricultural commodities from domestic production adequate to meet the domestic and foreign demand at prices fair both to producers and consumers and (2) as a means of administering and supplementing marketing quotas designed for the same purpose.

Marketing Quotas. A farm marketing quota is a quantity of a given agricultural commodity determined in advance as that required to supply the nation's domestic consumption and export needs without excess and adopted by those in administrative responsibility as a basis of determining the amounts to be allocated for marketing among the states, counties, and farms. The criteria for determining these quotas have varied from time to time according to the commodity and particular act under which the quota has been administered. Enforcement is by means of a price penalty for violation of the quota.

Marketing quotas have been promulgated as have acreage allotments as a direct means of maintaining a continuous and stable supply of agricultural commodities at prices assumed to be fair to both producers and consumers. Furthermore, marketing quotas have been made a condition, acceptance of which by producers has been a requirement for a given level of price support.

Marketing Agreements. A marketing agreement may be either state or federal. In California it is a contract entered into voluntarily between either the State Department of Agriculture or the United States Secretary of Agriculture on the one hand and handlers of the commodity on the other. While surplus control and price stabilization are major objectives of the marketing agreement, its functions are to regulate both quantity and quality of a commodity reaching the market. The marketing agreement applies to a limited area.

Marketing Orders. Marketing orders like marketing agreements apply to limited areas. They may or may not establish minimum prices. Their major difference from a marketing agreement is that they apply by law to all of the handlers of the commodity within the area to which they apply. The marketing order and marketing agreement may both be features of the same program. The California Milk Marketing Act has many features similar to those of a marketing order.

Other Devices. A number of other activities such as purchase and diversion of surpluses, subsidy payments to exporters, consumer subsidies or price differentials, and tariffs all seek to improve producers' incomes.

Price Stabilization and Crop Acreage Trends. Of the above devices applied for the purpose of stabilizing and improving farm income, the acreage allotment and the marketing quota are the only ones that limit acreage expansion. The others may or may not be combined with marketing quotas, acreage allotments, or both for the purpose of preventing runaway acreage expansion in response to improved farm income. It is not the purpose here to express an opinion regarding the merits of the legislation which embodies various combinations of the above devices as applied to the different crops. The basic question here is: *How are the long-term projections presented in Table 6 likely to be affected by different possible lines of political action?* The three most likely alternative policies expressed in broad terms are assumed as follows:

1. Retention of the main body of price stabilization legislation with further refinements in the direction of marketing quotas and/or acreage allotments, combined with each price-support measure.
2. Gradual removal of all price stabilization measures.
3. Expansion of voluntary types of control measures within the various agricultural industries.

Effective price stabilization, it would seem, would tend to concern itself with the variations about the trend and not with the trend itself. Any attempt to hold down a natural trend by rigid control measures would seem to be likely to result ultimately in a forced adjustment. A tentative assumption can be made, therefore, that *long-term national trends will be the same with and without price stabilization legislation.*

Some qualification of the above assumption must be made, however, in regard to trends in California compared with national trends. The state acreage allotment for any basic commodity will determine its share in the national allotment. There is some possibility that adherence to existing formulae may prevent natural shifts in production to areas in California which recently have demonstrated a superior advantage with respect to quality of product and economy of production. Retention of existing price stabilization legislation, therefore, may cause the acreage of a basic commodity like cotton to fall below the projected trend and to approach more nearly a rate of increase in accord with projected United States population increase modified by trends in per-capita consumption and projected demand for export. The 1954 projected trend for cotton, however, is well below the 936,408 acres approved January 7, 1954, for allotment to California by the United States Senate Committee on Agriculture. It would seem that, in the light of uncertainty of future legislation, a recalculation of the cotton projection would not be justified. The element of uncertainty, however, thus injected by political action and competition between the states cannot be entirely ignored.

The other two "basic" crops of importance to California are rice and wheat. Each like cotton is affected by the hazards of an export market. In the legislation providing price support for these crops, there are provisions for trend, but each like cotton must share any increase in trend with the other states. In fact, the small percentage increase allowed for trend in most of the acts is generally allocated to the small-scale producers of other states.

The nonbasic crops, on the other hand, while subject in many cases to the acceptance of marketing quotas and acreage allotments as conditions for price support, either represent crops which are highly specialized in California where a large part of the total national production is centered or are feed crops not affected directly by price-support programs. For most of these crop groups, trend values should not be expected to be greatly changed by price stabilization legislation. Some of them seek price stabilization through marketing agreements which apply to limited areas. Trend values should not be affected by such localized price-support measures, especially if accompanied by marketing quotas. Many of the feed crops are affected indirectly through various state legislation affecting the dairy industry. These also have local or regional significance but should not affect long-term trends.

The general conclusions with respect to this immediate question of the probable effect of price stabilization upon long-term acreage trends are: (1) there is no indication that there will be sufficient certainty of legislation which will affect trends which would warrant making allowance for it; (2) in general, price stabilization if accomplished should affect variations from the trend more than the trend itself; and (3) in relation to some basic crops, a long continued acreage allotment policy, such as that implied by existing legislation, could affect the long-term trend in California's share in the national allotment and thereby affect the trend as projected.

CONCLUSIONS

Conclusions may be drawn with respect to the California projected statewide crop pattern by again calling attention to Table 6 which itself is a one-page summary of the entire study. In referring to the percentage distribution of that table, however, it must be emphasized again that, although it was tentatively assumed to be applicable for 1980, it may better be considered as applicable to a stage of development which is expected to be reached as California approaches the full utilization under irrigation of her irrigable area. That time may be 1980 or before or after that time. It represents not a specific date but a given stage of agricultural development. This stage in agricultural development also represents an important stage in the development of California's water resources. Although the crop pattern is presented as that which may be assumed for an initial stage of full development, the water requirement for that crop pattern is assumed to be the same as that for a later stage that has been referred to as a stage of "ultimate development."

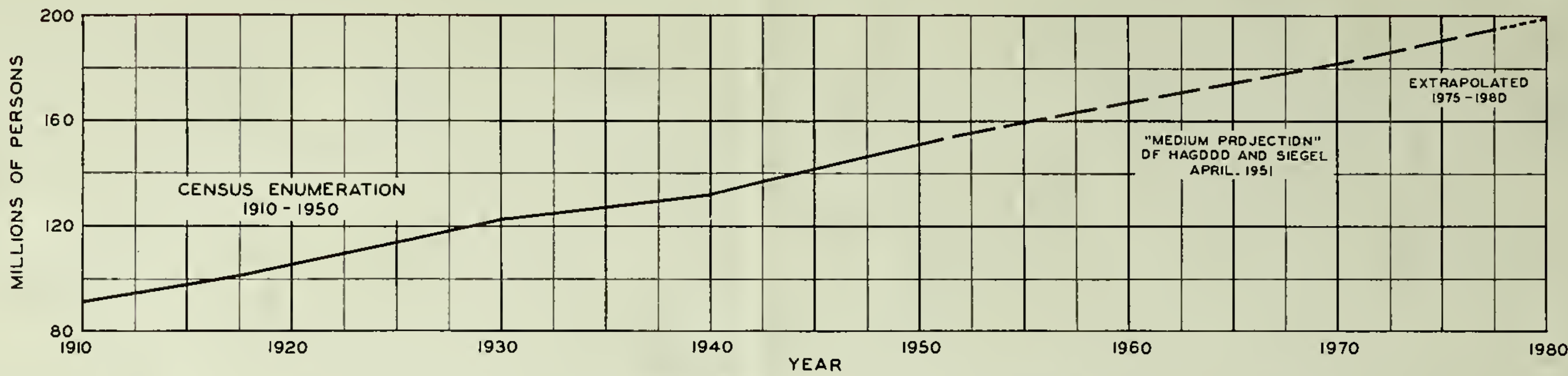

FIG. 1A. POPULATION OF THE UNITED STATES (INCLUDING MILITARY FORCES OVERSEAS)

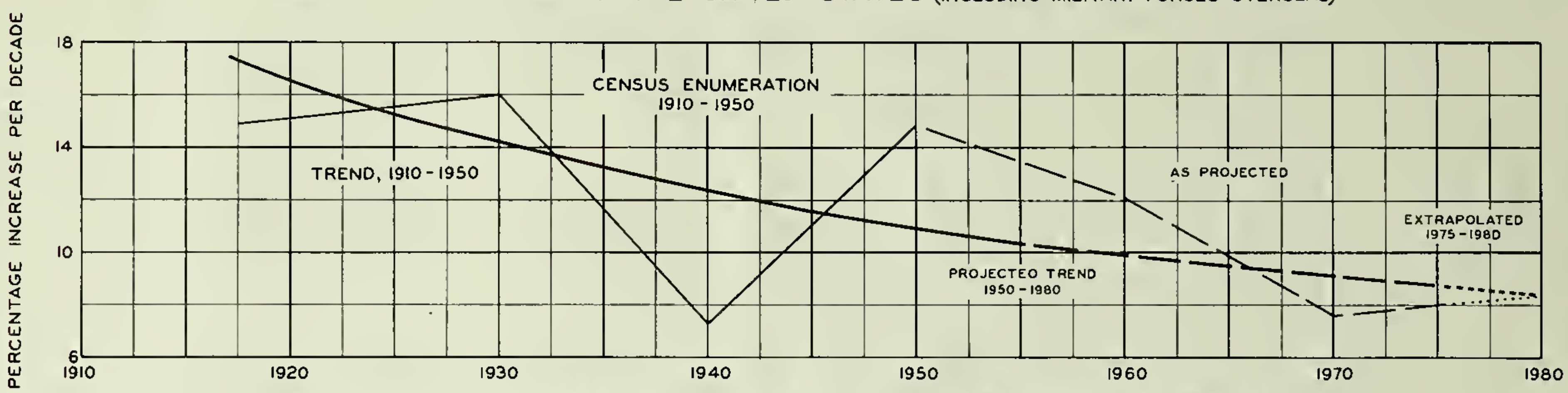

FIG. 1B. PERCENTAGE INCREASE PER DECADE OF UNITED STATES POPULATION

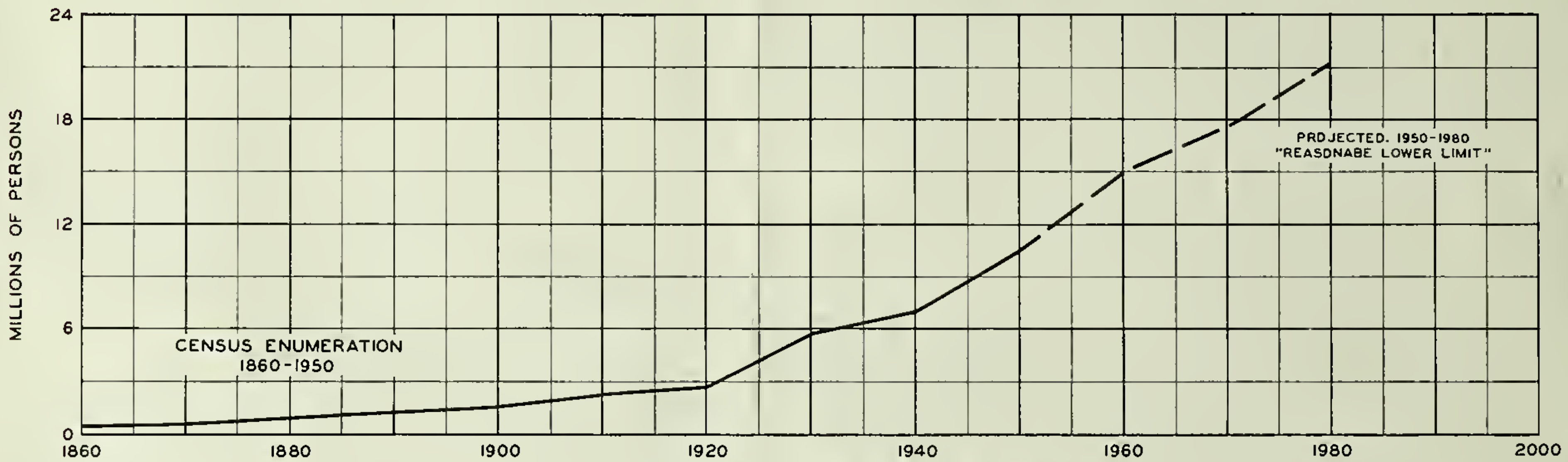

FIG. 1C. POPULATION OF CALIFORNIA

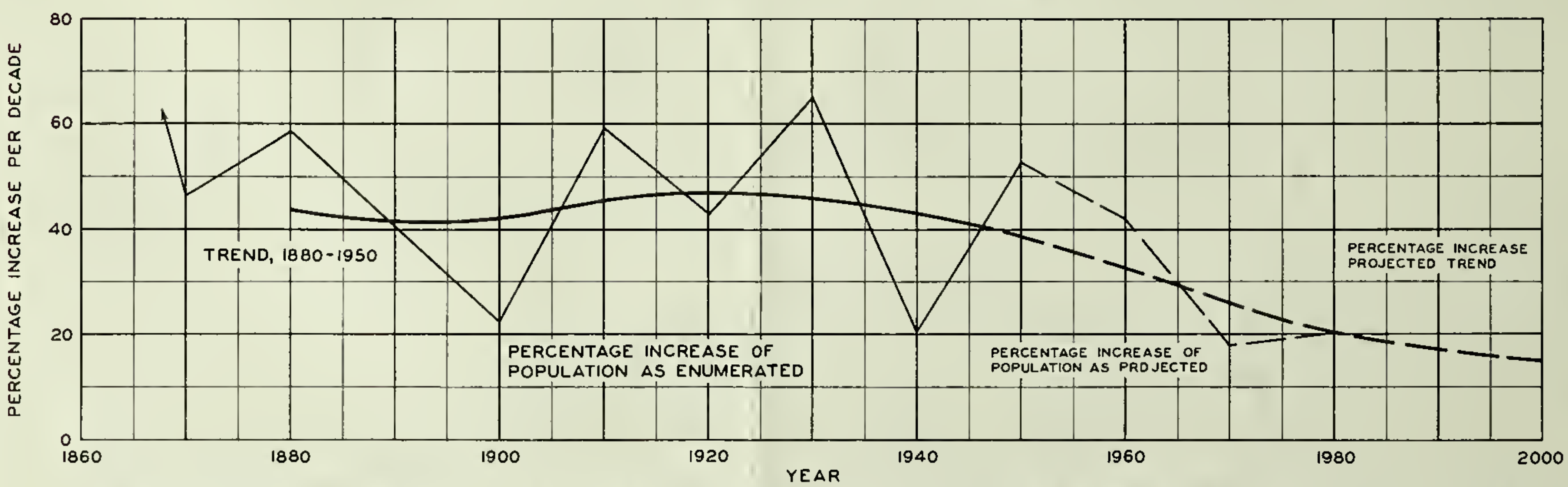

FIG. 1D. PERCENTAGE INCREASE OF CALIFORNIA POPULATION OVER THE POPULATION TEN YEARS EARLIER

PROJECTED POPULATION OF UNITED STATES AND CALIFORNIA

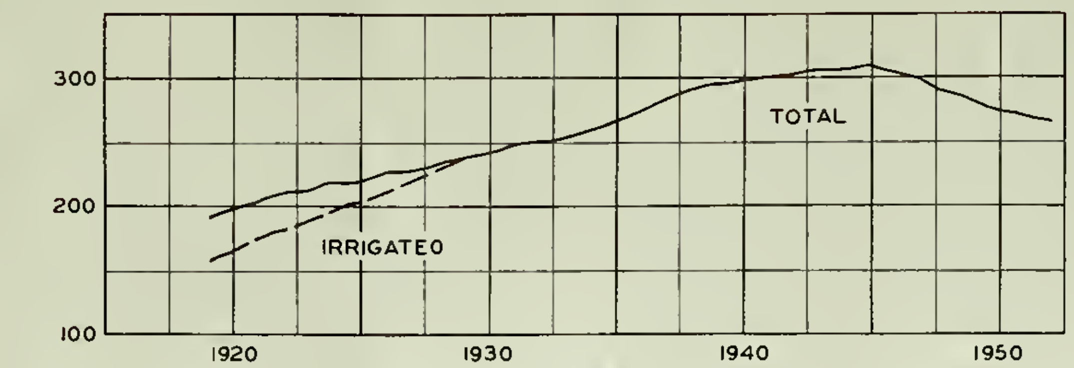

Fig. 2A. CITRUS FRUITS

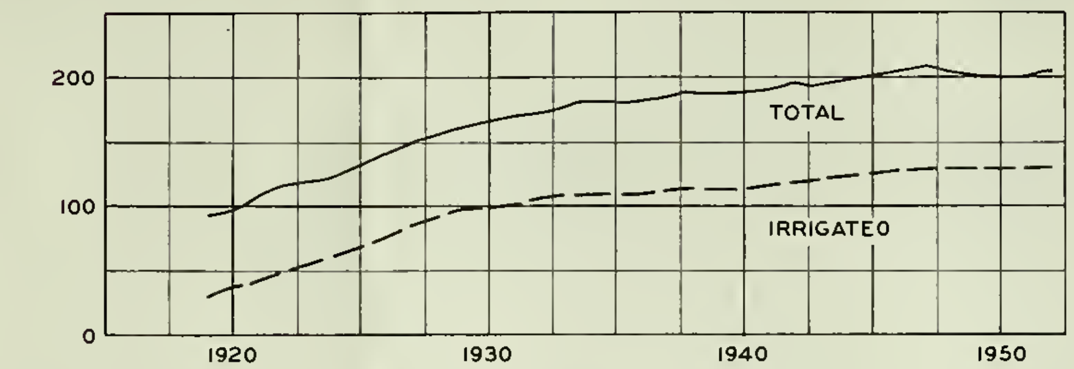

Fig. 2B. NUT CROPS

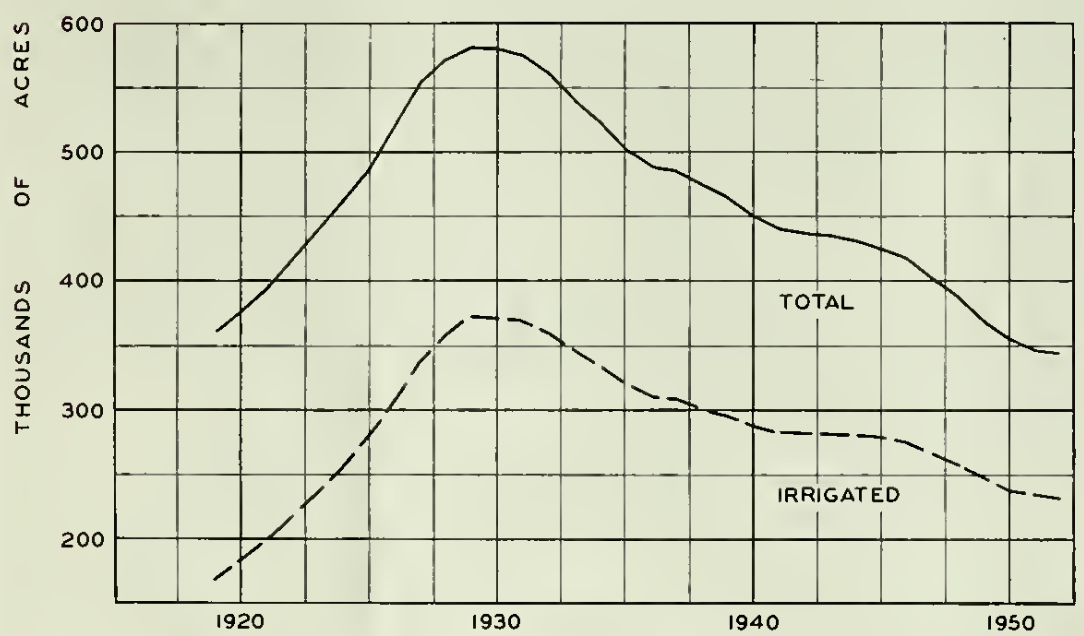

Fig. 2C. DECIDUOUS TREE FRUITS

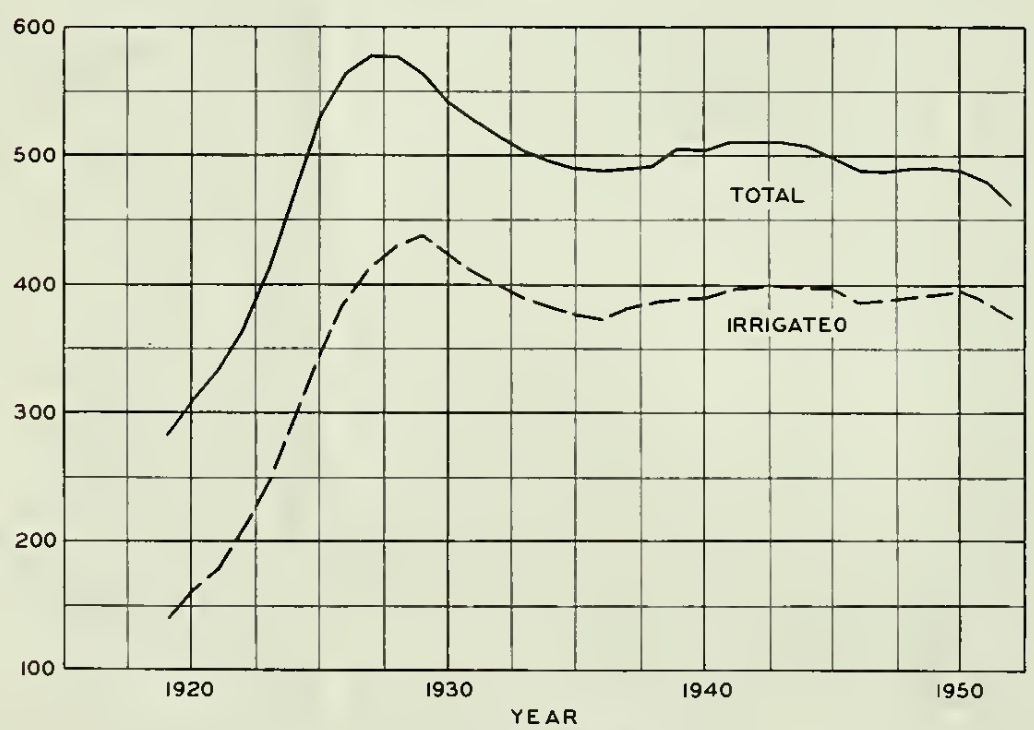

Fig. 2D. VINEYARD

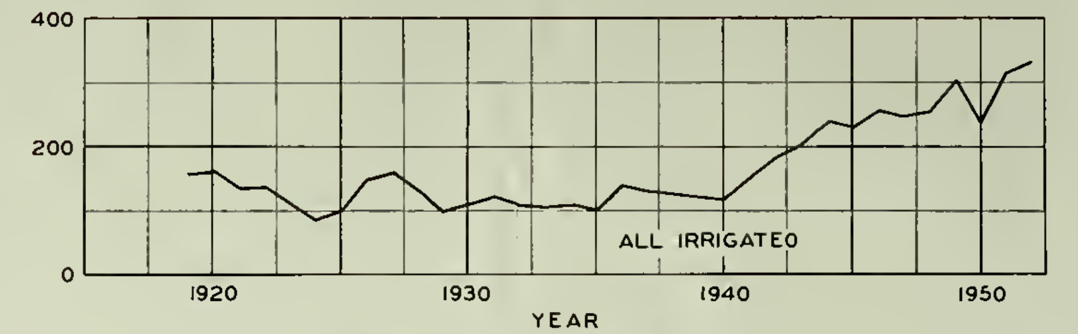

Fig. 2E. RICE

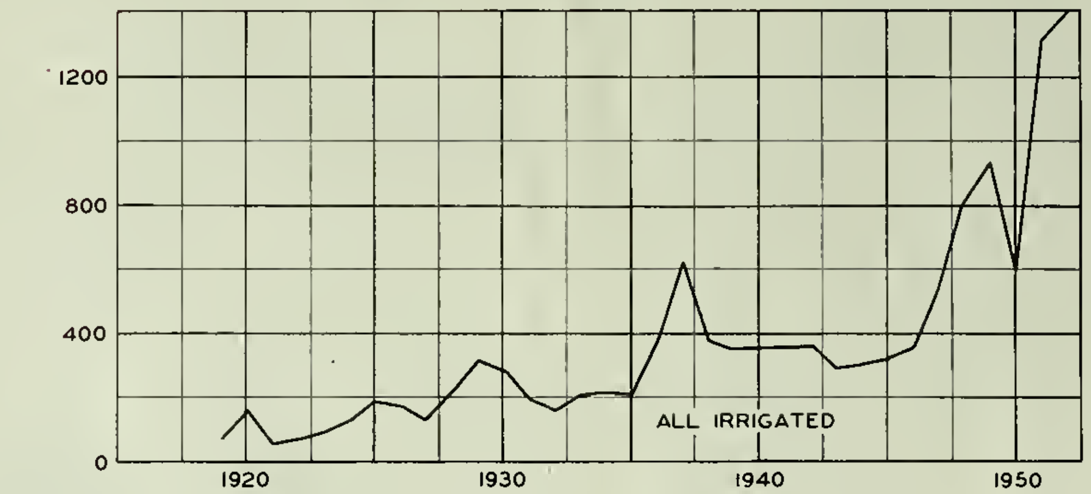

Fig. 2F. COTTON

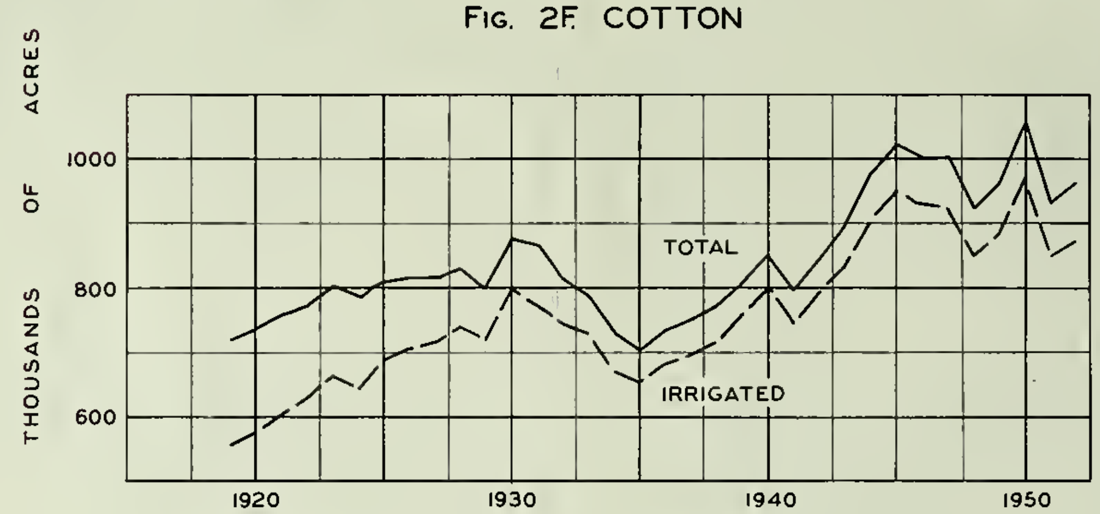

Fig. 2G. ALFALFA

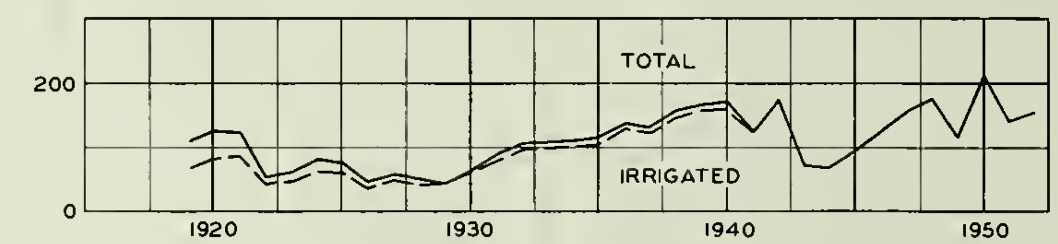

Fig. 2H. SUGAR BEETS

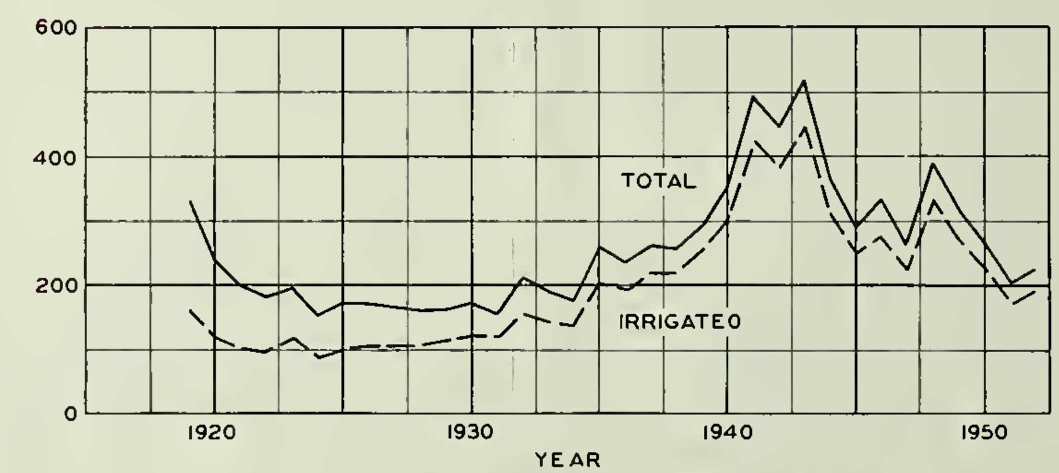

Fig. 2I. CORN, SORGHUMS, HOPS AND FLAX

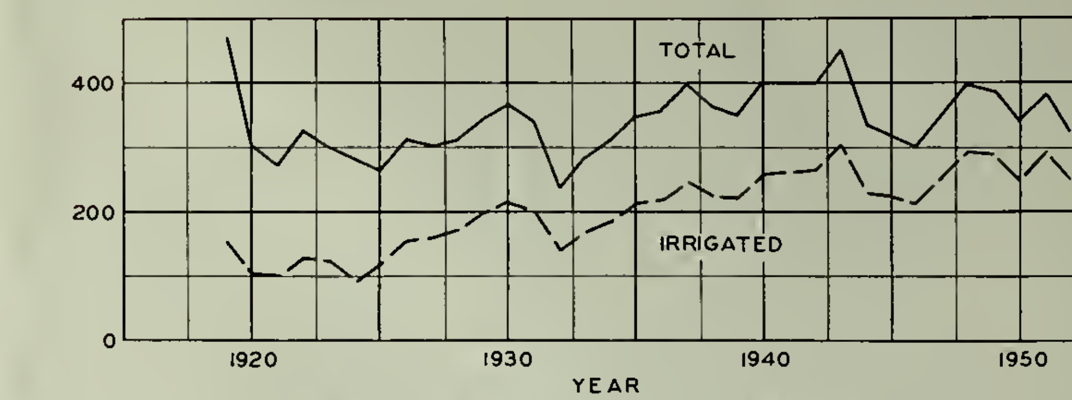

Fig. 2J. BEANS, GREEN AND DRY

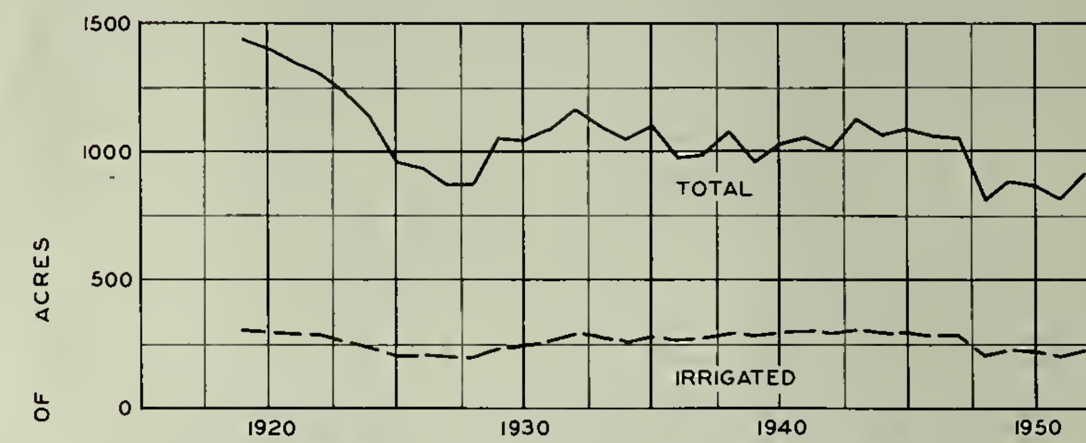

Fig. 2K. EXTENSIVE HAY CROPS (WILD GRAIN AND OTHER TAME HAY EXCLUDING ALFALFA)

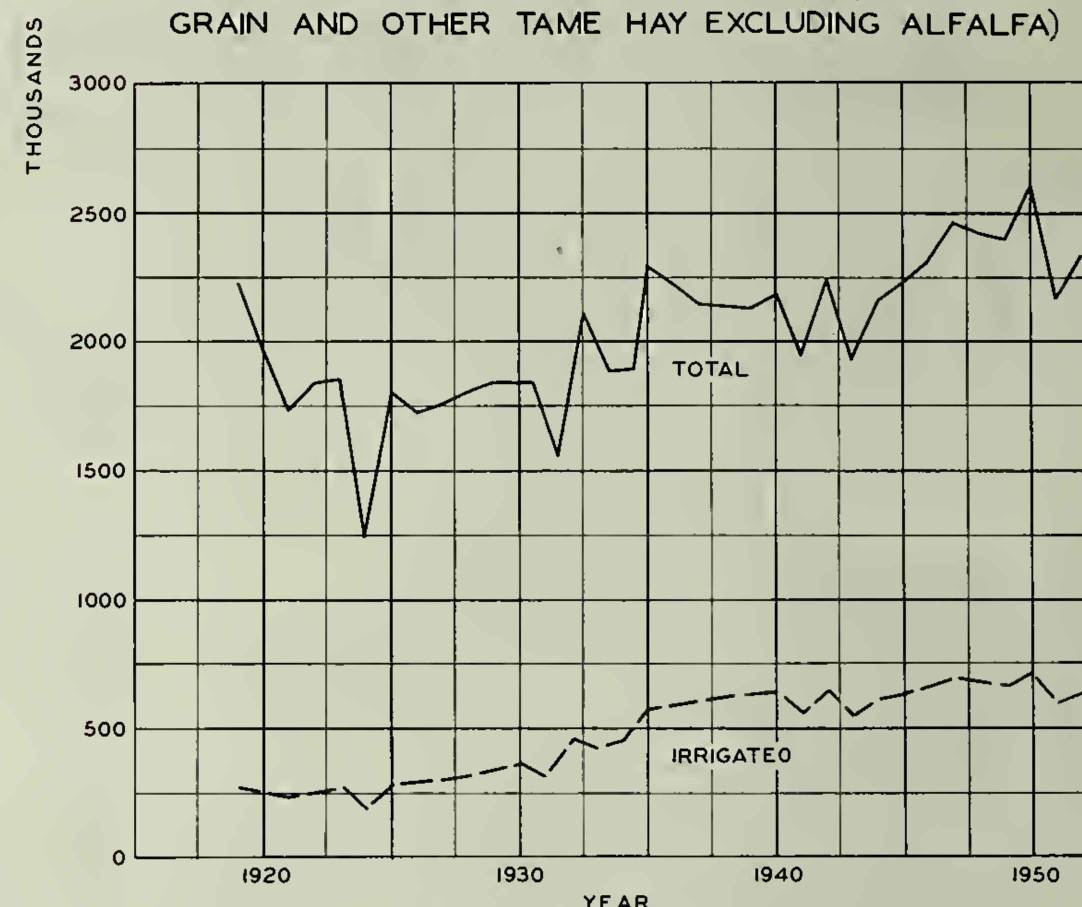

Fig. 2L SMALL GRAINS

TOTAL AND IRRIGATED ACREAGE OF CALIFORNIA CROPS

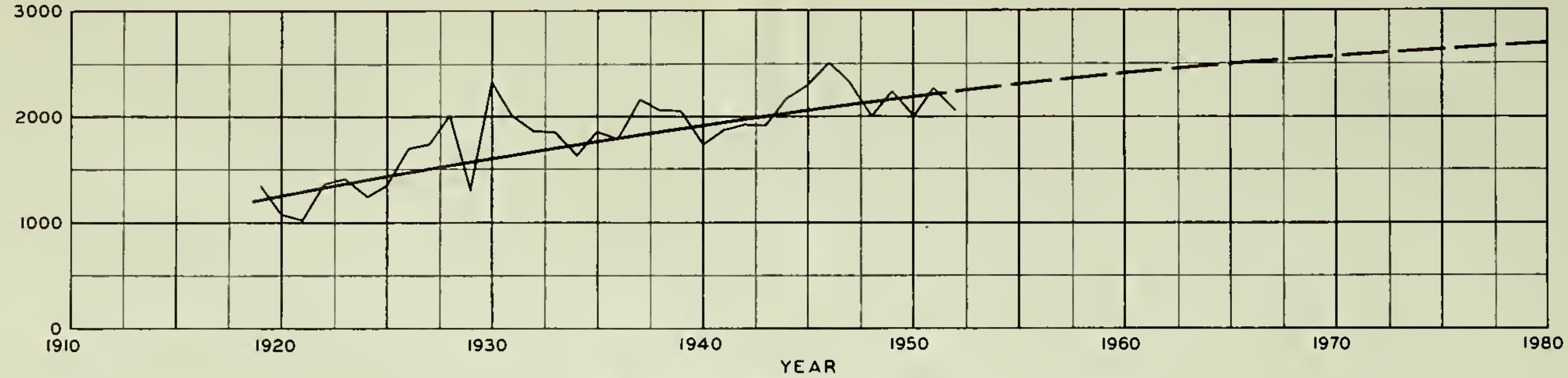

FIG. 3A. DECIDUOUS FRUIT TREE

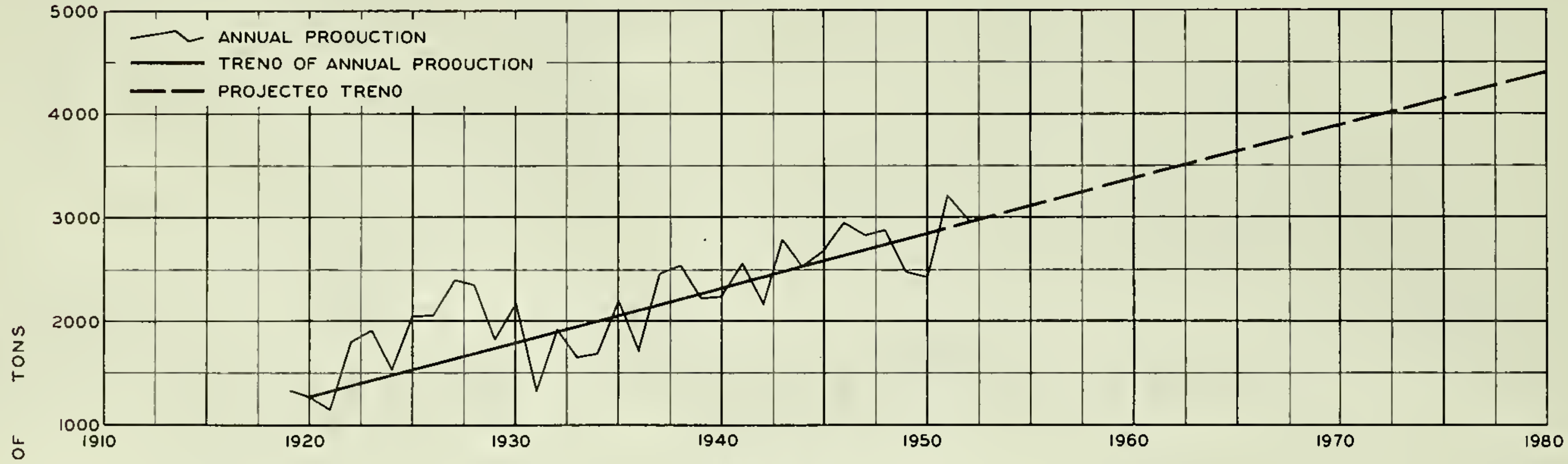

FIG. 3B. GRAPE

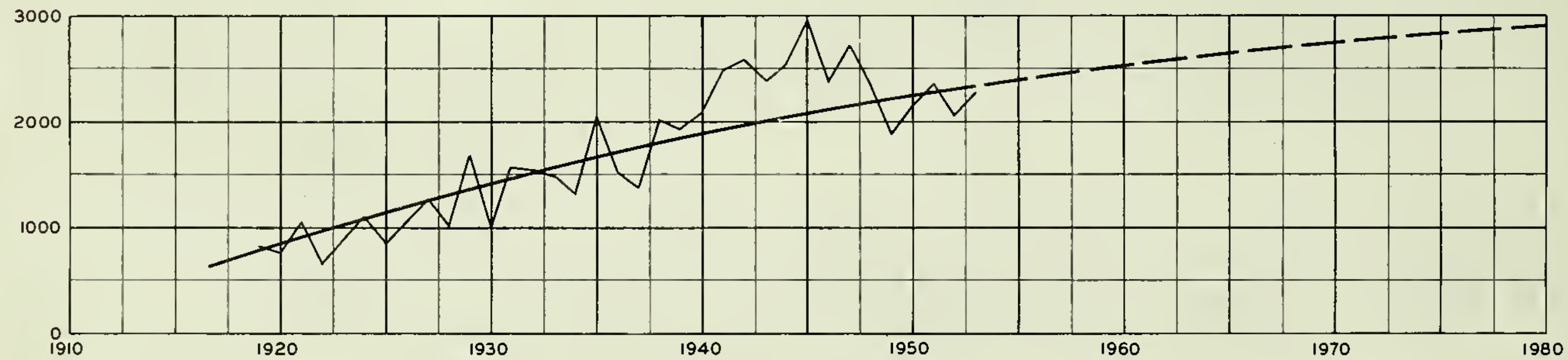

FIG. 3C. CITRUS FRUIT

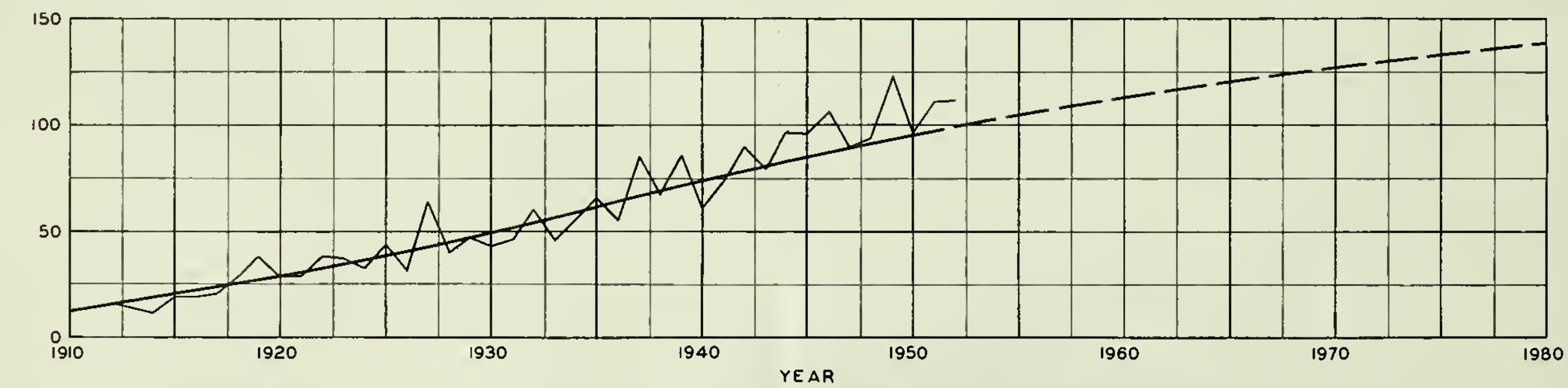

FIG. 3D. NUT CROP

CALIFORNIA FRUIT, GRAPE AND NUT PRODUCTION

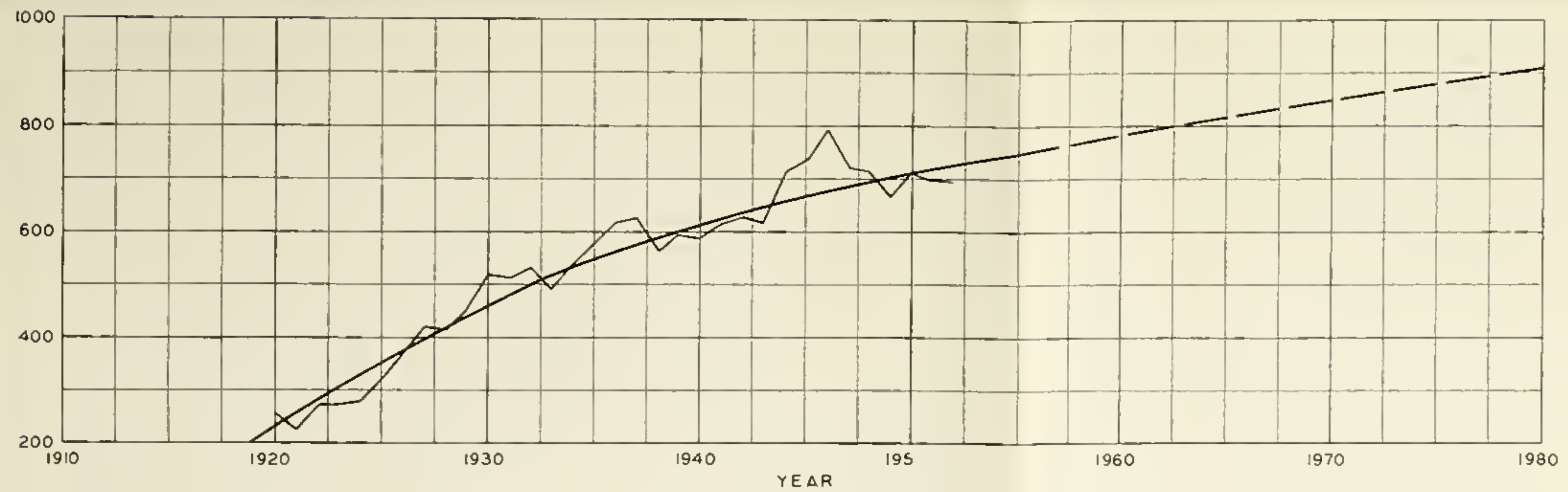

FIG. 4A. TRUCK CROPS

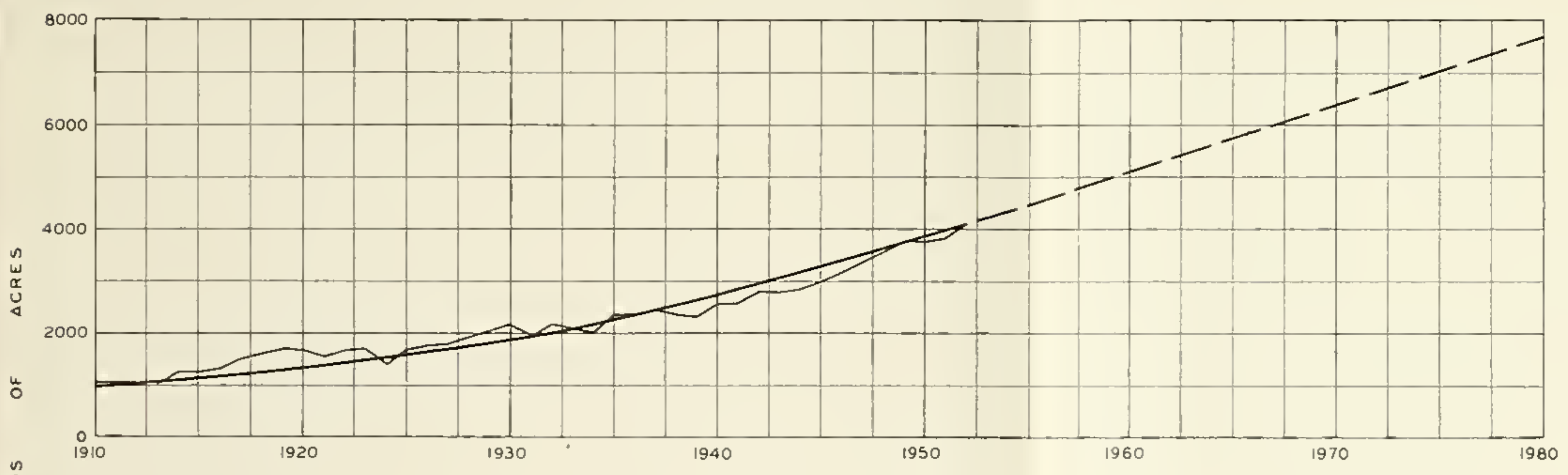

FIG. 4B. FIELD CROPS

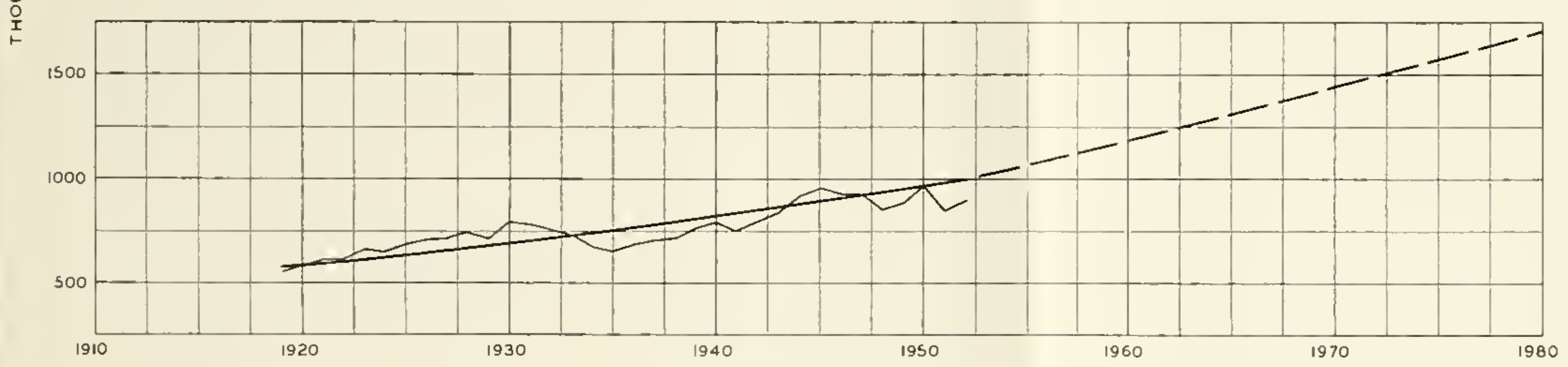

FIG. 4C. ALFALFA

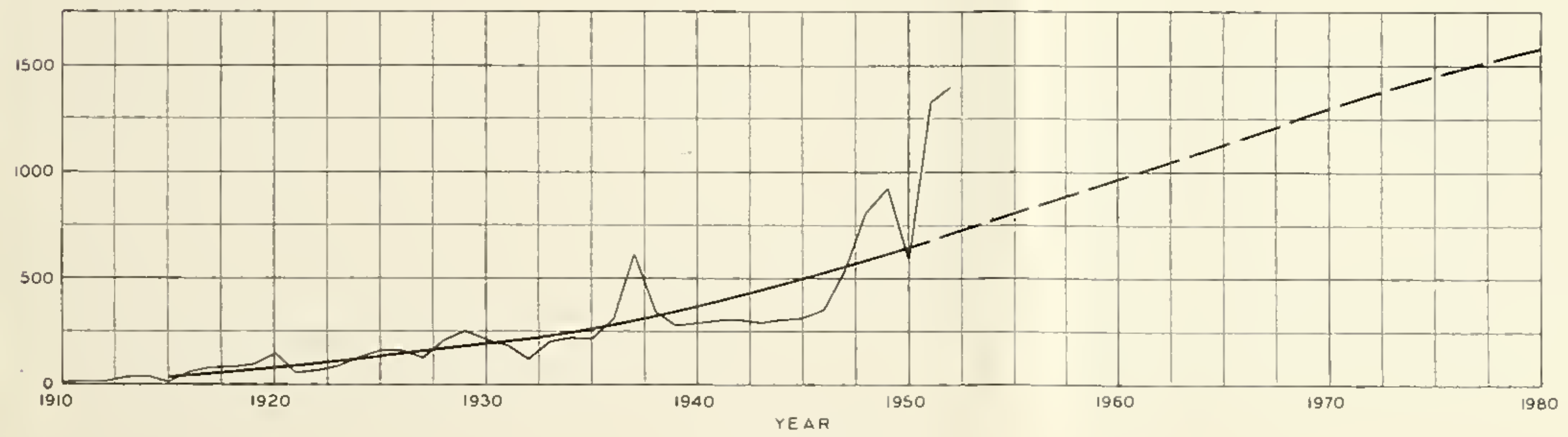

FIG. 4D. COTTON

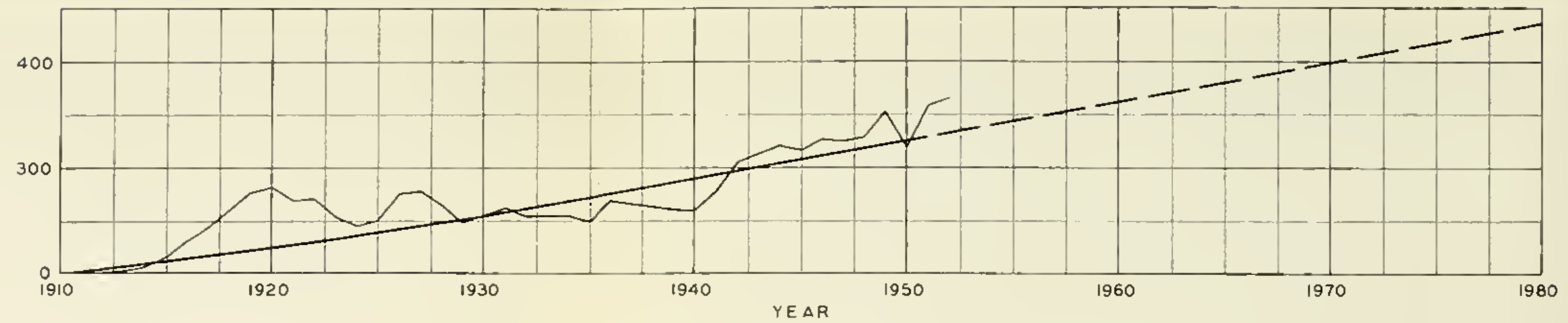

FIG. 4E. RICE

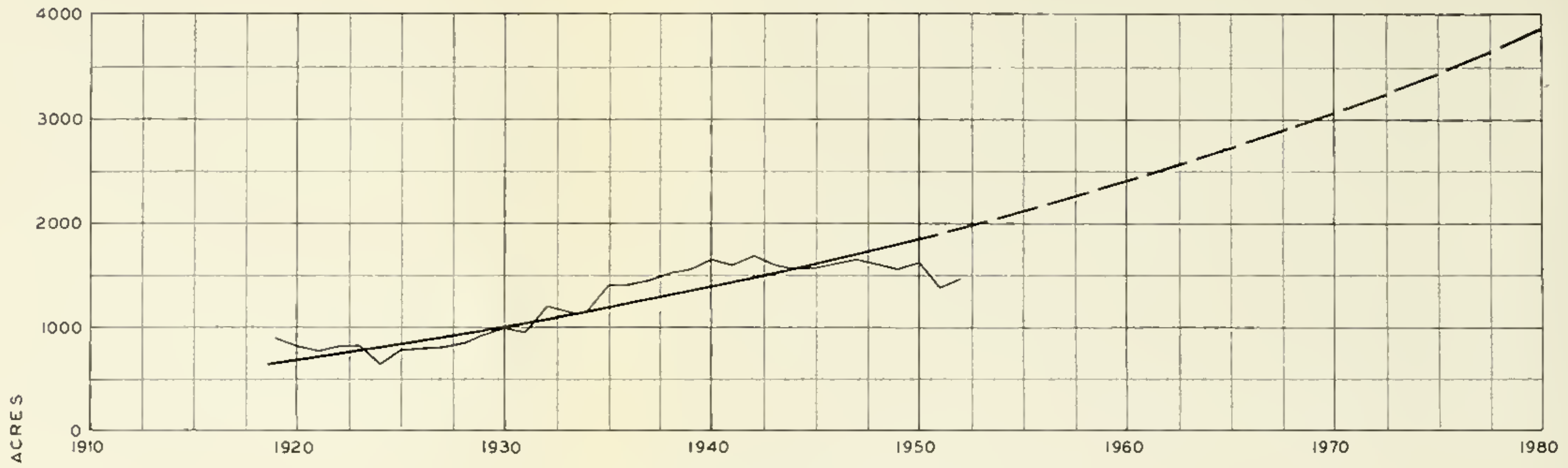

FIG. 4F. MISCELLANEOUS FIELD CROPS

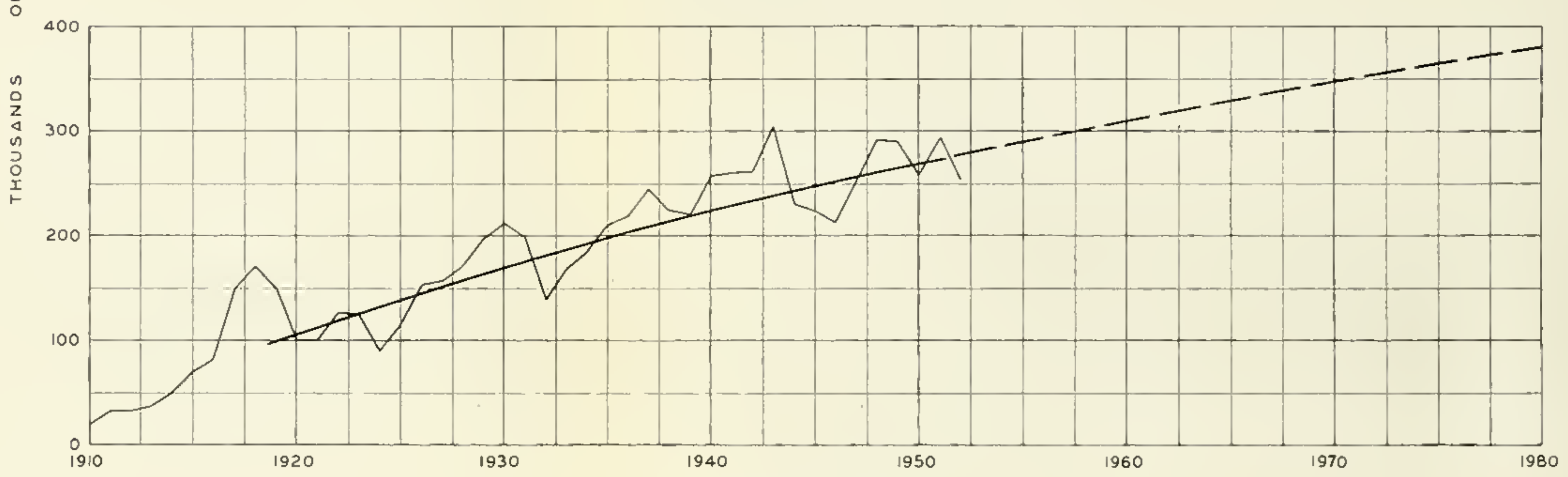

FIG. 4G. BEANS

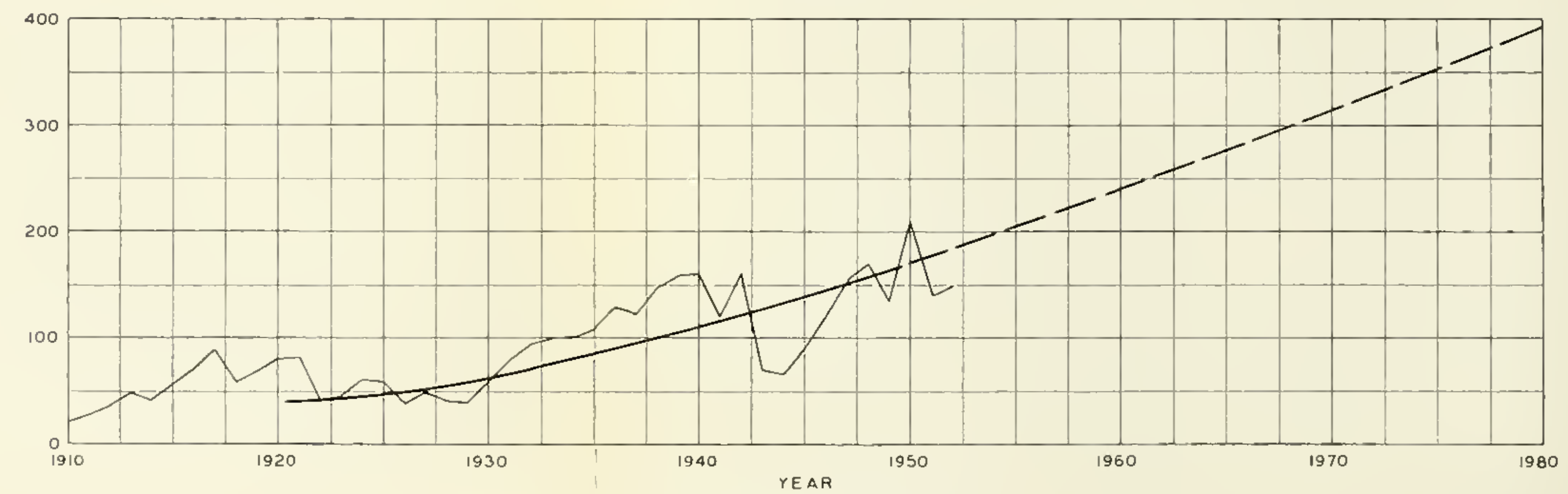

FIG. 4H. SUGAR BEETS

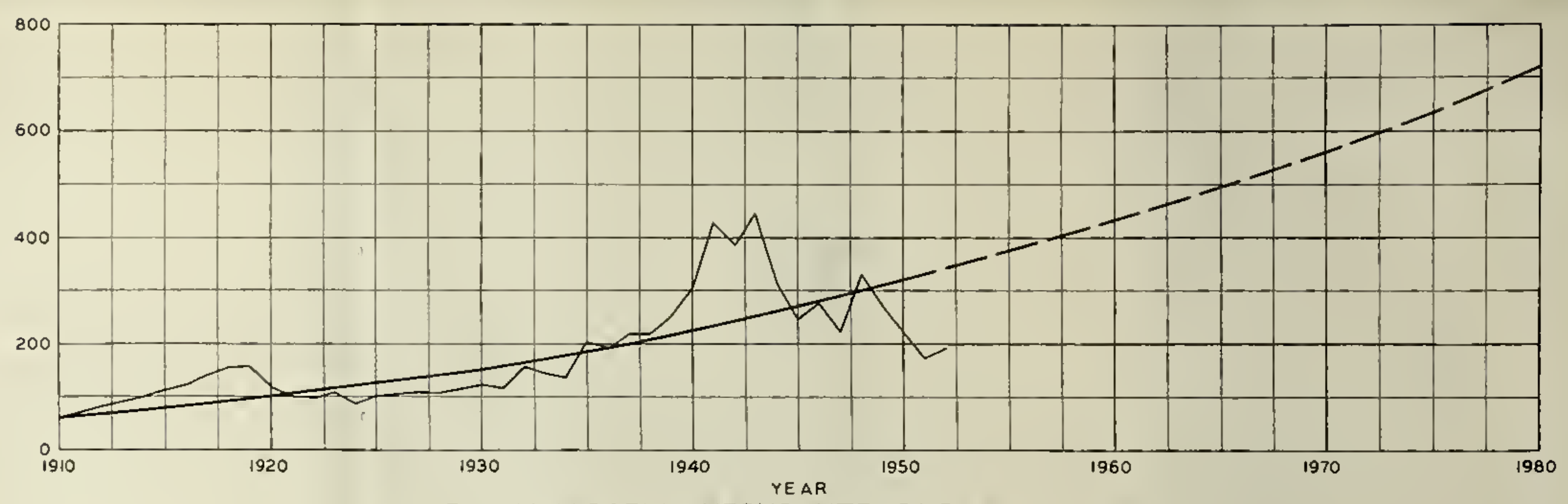

FIG. 4 I. MISCELLANEOUS, INTENSIVE FIELD CROPS

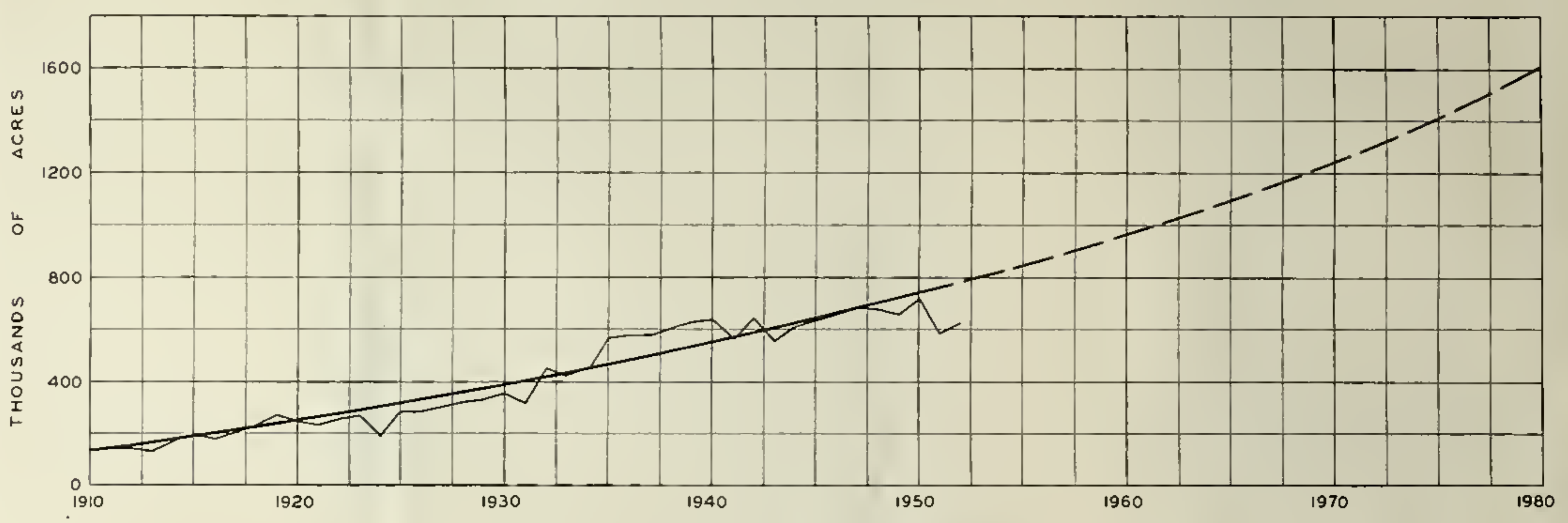

FIG. 4J. SMALL GRAIN CROPS

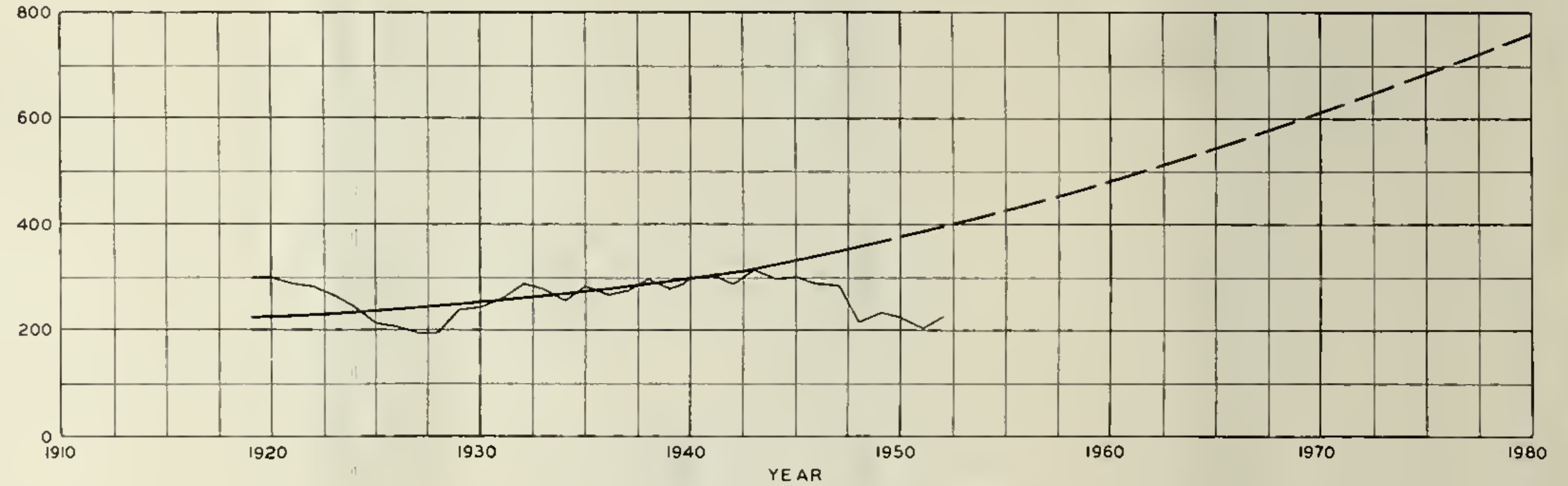

FIG. 4K. EXTENSIVE HAY CROPS

IRRGATED HARVESTED ACREAGE
TRENO OF IRRIGATED HARVESTED ACREAGE
PROJECTEO TRENO

IRRIGATED HARVESTED ACREAGE
OF
CALIFORNIA CROPS

APPENDIX B

DIRECTORY OF WATER SERVICE AGENCIES IN CALIFORNIA

TABLE OF CONTENTS

DIRECTORY OF WATER SERVICE AGENCIES IN CALIFORNIA

DIRECTORY OF WATER SERVICE AGENCIES IN CALIFORNIA

INTRODUCTION

One of the major factors contributing to the phenomenal growth of California has been the favorable political climate for local community water development. This environment, expressed through laws and policies of the State Government, has permitted the formation of local organizations to cope with and resolve water problems, and to meet as they occurred the many municipal, industrial, and agricultural water demands. Presently there are more than 2,500 such organizatons in the State.

As a part of the investigation of present water utilization in California, a list was compiled of the agencies which serve, distribute, or sell water for domestic, irrigation, or other uses. This directory is presented hereinafter in tabular form.

Introductory to the directory, there follows a brief description of the principal classes and types of local community water service agencies in California. There are two principal types of such agencies, privately owned and public. The privately owned agencies may, in turn, be divided into two general classes, commercial water companies and mutual water companies. The principal classes of publicly owned agencies are public water districts and municipal waterworks.

Commercial Water Companies

Commercial water companies are organized for the purpose of building and operating waterworks for the profit of persons who will provide the capital for and own the systems. They differ from mutual water companies and public agencies in that both of the latter are nonprofit cooperative enterprises under local ownership and control. Ownership of the assets of a commercial water company may be held by persons who live outside of the water service area. Such companies are usually incorporated, although an individual may engage in public utility service of water. Most commercial water companies in California operate under the jurisdiction of the State Public Utilities Commission, and must serve water to all applicants within their service areas, as specified in certificates of convenience issued by the Public Utilities Commission.

Mutual Water Companies

Mutual water companies, sometimes called "cooperatives," are private associations of people, organized for the purpose of providing water at cost, primarily for the use of their members. Such companies are voluntary, nonprofit enterprises, and are controlled by their members or stockholders. They have no obligation to serve water to any but their members and stockholders. This contrasts with the obligations of water districts and commercial companies, under which service must be extended to all consumers within such agency's service area if water is available. Mutual water companies may or may not be incorporated, and do not come within the jurisdiction of the Public Utilities Commission.

Public Water Districts

Early in the statehood of California the people recognized that privately owned and operated water service organizations could not cope with all the water problems that were developing. Through their Legislature, therefore, they enacted the first of many laws providing for public districts to accomplish certain desirable purposes. It is notable that nearly all public water districts, unlike mutually owned enterprises, have the power of assessment of the lands of the districts and of eminent domain. The first of the water district laws was the Reclamation District Act of 1867. The first law authorizing formation of irrigation districts was enacted by the Legislature in 1872. However, the Wright Act of 1877 has formed the basis for virtually all irrigation district legislation subsequently enacted in California. Since that time, as new or more pressing water problems arose requiring public action, the Legislature has passed many acts authorizing formation of different types of districts to meet different circumstances.

There are at present two principal methods in this State of forming water districts. One is the enactment by the Legislature of a general act, under which any number of districts may be formed in accordance with a procedure set forth in the act. The other method is by a special act of the Legislature creating a particular district and prescribing its powers. Under the general water district acts, there are specific provisions requiring notice and hearing of petitions for formation, which for the most part are conducted by county boards of supervisors. Under the second method, notice and hearing are afforded by the legislative process, whereby the authorizing bills are heard in committee and on the floor of the Legislature.

California statutes presently authorize the formation of more than 30 types of districts relating to the development, conservation, use, disposal, and avoidance of water, and most of these districts may provide water service. There follows a list of general water district acts, together with the year of the original authorizing legislation.

Community Services Districts (1951)
County Recreation Districts (1931)

County Water Authorities (1943)
County Water Districts (1913)
County Waterworks Districts (1913)
Drainage Districts (1885)
Drainage Districts (1903)
Drainage Districts (1919)
Flood Control and Flood Water Conservation Districts (1931)
Irrigation Districts (1897)
Levee Districts (1905)
Metropolitan Water Districts (1927)
Municipal Utility Districts (1921)
Municipal Water Districts (1911)
Municipal Water Districts (1935)
Protection Districts (1880)
Protection Districts (1895)
Protection Districts (1907)
Public Utility Districts (1921)
Reclamation Districts (1867)
Resort Districts (1931)
Storm Drain Maintenance Districts (1937)
Storm Water Districts (1909)
Water Districts (1913)
Water Conservation Districts (1927)
Water Conservation Districts (1931)
Water Replenishment Districts (1955)
Water Storage Districts (1921)
Water Storage and Conservation Districts (1941)

Most but not all of the foregoing listed acts have been used by interested groups to form water districts. The purposes, powers, restrictions, and privileges, which vary with each act, are briefly described and compared in a periodic publication of the Division of Water Resources entitled "General Comparison of California Water District Acts."

In addition to the water districts formed pursuant to the foregoing general district acts, more than 30 districts have been formed under special acts of the Legislature. The Legislature has constitutional authority to organize taxation districts with boundaries defined in the legislative act, without submitting the question to a vote of property owners within the area. Most of such special water districts are countywide in area, and may be regarded as a natural outgrowth of the local district organization movement as the water problems became more and more complex. Inasmuch as most of these districts have been created of recent years, only a few to date have actively entered into water development activities. The following list is indicative of the districts formed under special acts, whose powers include the development, disposal, and/or sale of water. The year shown for each district is that in which it was created by the Legislature. These likewise are briefly described and compared in the publication cited in the preceding paragraph.

Alameda County Flood Control and Water Conservation District (1949)
American River Flood Control District (1927)
Avenal Community Services District (1955)
Brisbane County Water District (1950)
Contra Costa County Flood Control and Water Conservation District (1951)
Contra Costa County Storm Drainage District (1953)
Del Norte County Flood Control District (1955)
Donner Summit Public Utility District (1950)
Humboldt County Flood Control District (1945)
Kings River Conservation District (1951)
Lake County Flood Control and Water Conservation District (1951)
Los Angeles County Flood Control District (1915)
Marin County Flood Control and Water Conservation District (1953)
Mendocino County Flood Control and Water Conservation District (1949)
Montalvo Municipal Improvement District (1955)
Monterey County Flood Control and Water Conservation District (1947)
Morrison Creek Flood Control District (1953)
Napa County Flood Control and Water Conservation District (1951)
Olivehurst Public Utility District (1950)
Orange County Flood Control District (1927)
Orange County Water District (1933)
Riverside County Flood Control and Water Conservation District (1945)
Sacramento County Water Agency (1952)
San Benito County Water Conservation and Flood Control District (1953)
San Bernardino County Flood Control District (1939)
San Diego County Flood Control District (1945)
San Luis Obispo County Flood Control and Water Conservation District (1945)
Santa Barbara County Flood Control and Water Conservation District (1955)
Santa Barbara County Water Agency (1945)
Santa Clara County Flood Control and Water Conservation District (1951)
Santa Cruz County Flood Control and Water Conservation District (1955)
Solano County Flood Control and Water Conservation District (1951)
Sonoma County Flood Control and Water Conservation District (1949)
Vallejo Sanitation and Flood Control District (1952)
Ventura County Flood Control District (1944)
Yolo County Flood Control and Water Conservation District (1951)

Municipal Waterworks

One of the major classes of publicly owned water service agencies in California consists of municipally owned waterworks, which, in general, serve water within the municipal boundaries. Approximately 200 cities in California now own and operate their own waterworks.

DIRECTORY OF WATER SERVICE AGENCIES IN CALIFORNIA

The following tabulation of water service agencies in California presents the data by counties in each hydrographic area. Information on the number of domestic consumers and on the number of irrigated acres, as well as the approximate location of the service area of each agency, is included in the tabulation. The period during which this information was collected was from 1950 through 1954.

Inasmuch as there is a continuing process of formation of private and public water service agencies, and also a process of dissolution or annexation of such agencies, the directory, although the most complete and comprehensive known to have been made to date, is not warranted to include all such agencies that may exist in California.

10—99801

WATER SERVICE AGENCIES, NORTH COASTAL AREA

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Del Norte County			
Commercial Water Companies			
Crescent City Water Company	Crescent City		1,154
Hunter Water Company	Crescent City		10
Klamath Glen Subdivision Water Service	Klamath		125
Klamath Water Company	Klamath		125
McBeth Acres Water System	Klamath		39
Smith River Water Service	Smith River		105
Mutual Water Companies			
Gasquet Mutual Water Company	Crescent City		28
Humboldt County			
Municipal Waterworks			
Arcata	Arcata		1,585
Blue Lake	Blue Lake		255
Eureka	Eureka		7,615
Fortuna	Fortuna		930
Trinidad	Trinidad		100
Commercial Water Companies			
Benbow Water Company	Benbow		30
Campton Heights Water Service	Rohnerville	30	175
Fields Landing Water Works	Fields Landing		134
Francis Land and Water Company	Ferndale		480
Garberville Water Company, Inc.	Garberville		233
Humboldt Hill Water Service	Bucksport		3
Loleta Water Works	Loleta		142
Myers Water Works	Myers Flat		70
Phillipsville Water Company	Phillipsville		34
Redway Water Company	Redway		180
Rio Dell Water System	Rio Dell		359
Riverside Water Works	Ferndale		67
Rohnerville Water Works	Rohnerville		139
Weott Water Company	Weott		120
Willow Creek Water Works	Willow Creek	25	50
Mutual Water Companies			
Arcata Airport Water Supply	Arcata		30
Big Lagoon County Water Supply	Trinidad		79
Carlotta Water Supply	Carlotta		14
East Highway Water Company	Eureka		4
Fickle Hill Water Supply	Fickle Hill		30
Fort Seward Water Supply	Fort Seward		2
Hagwood's Orick Water Supply	Orick		14
King Salmon Mutual Water Company	Fields Landing		20
Korbel Water Supply	Korbel		104
Orick Water Company	Orick		17
Port Kenyon Water Supply	Ferndale		71
Samoa Water Supply	Eureka		135
Scotia Water Supply	Scotia	150	354
Marin County			
Commercial Water Companies			
Coast Springs Water Company	Dillon Beach		117
Mendocino County			
Municipal Waterworks			
Fort Bragg	Fort Bragg		1,291
Ukiah	Ukiah		2,375
Commercial Water Companies			
Brown's Water Works	Albion		12
Dos Rios Water Works	Dos Rios		10
Pacific Gas and Electric Company	Willits		914
Point Arena Water Works	Point Arena		111
Rogina Water Company	Talmage	28	145
Mutual Water Companies			
Caspar Lumber Company	Caspar		50
Laytonville Mutual Water Company	Laytonville		15
Oak Knolls Mutual Water Company	Ukiah		15
County Water Districts			
Willow County Water District	Ukiah		126
Round Valley County Water District	Covelo		
Mendocino County—Continued			
Irrigation Districts			
Potter Valley Irrigation District	Potter Valley	3,900	
Public Utility Districts			
Hopland Public Utility District	Hopland		75
Modoc County			
Irrigation Districts			
Tule Lake Irrigation District	Tulelake	30,000	
United States Bureau of Reclamation Projects			
Klamath Project	Tulelake	(See Siskiyou County)	
Siskiyou County			
Municipal Waterworks			
Dorris	Dorris		277
Etna	Etna		225
Montague	Montague		179
Tulelake	Tulelake		490
Yreka	Yreka		1,136
Commercial Water Companies			
Ball Water Company	Weed		56
Cottonwood Irrigation and Mining Company	Hornbrook		200
Dunsmuir Water Corporation	Fort Jones		198
Hornbrook Water Company	Hornbrook		56
Macdoel Water Works	Macdoel		9
Shastina Water Service	Shastina		375
Mutual Water Companies			
Champion Park Water Agency	Dunsmuir		24
Farmers Ditch Company	Etna	5,000	
Forks of Salmon Water Supply	Etna	50	2
Hilt Water System	Hilt		150
Klamath River Cooperative Ditch	Klamath River	325	4
Shasta River Water Association	Montague	3,895	
Tennant Water Supply	Weed		128
Van Fossen and Mason Water System	Dunsmuir		46
Irrigation Districts			
Big Springs Irrigation District	Grenada	2,100	
Butte Valley Irrigation District	Mt. Hebron	3,647	
Grenada Irrigation District	Grenada	1,394	
Montague Water Conservation District	Montague	3,450	
Scott Valley Irrigation District	Fort Jones	3,650	
Tule Lake Irrigation District	Tulelake	(See Modoc County)	
United States Bureau of Reclamation Projects			
Klamath Project	Tulelake	79,352	
Sonoma County			
Municipal Waterworks			
Cloverdale	Cloverdale		600
Healdsburg	Healdsburg		1,424
Santa Rosa	Santa Rosa		8,894
Sebastopol	Sebastopol		1,238
Commercial Water Companies			
Armstrong Valley Water Company	Guerneville		73
Bressie, V. L.	Bodega Bay		52
Camp Meeker Water System	Camp Meeker		302
Camp Rose Company	Camp Rose		93
Cazadero Water Company	Cazadero		121
Citizens Utilities Company of California	El Bonito Monte Rio Guerneville Rio Nido Guernewood Park		2,279
Del Rio Water Company	Del Rio		152
Geyserville Water Works	Geyserville		136

WATER SERVICE AGENCIES, NORTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services	Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Sonoma County—Continued				**Sonoma County**—Continued			
Commercial Water Companies—continued				Mutual Water Companies—continued			
Hacienda Water Company	Hilton		126	Mission Highlands Mutual Water Company	Sonoma		10
Horgan Water Company, C. J.	Hilton		7	Morton Water Service	Glen Ellen		11
Jenner Water Works	Jenner		66	Preston Heights Water Company	Cloverdale		1
Mountain Avenue Water Company	Fetters Springs		191	Russian River Mutual Water Company	Healdsburg	2	10
Occidental Water Works	Occidental		56	Salmon Creek Water Company	Bodega Bay		54
Rio Dell Water Company	Rio Dell		131	West Beach Mutual Water Company	West Beach		11
Russian River Terrace Water Company	Russian River Terrace		310	Willis Mutual Water Company	Santa Rosa		5
Summer Home Park Water Company	Sebastopol		138	Public Utility Districts			
Vacation Beach Water Company	Guerneville		128	Bodega Bay Public Utility District	Bodega Bay		
Windsor Utility Corporation	Windsor		54	Camp Rose Public Utility District	Healdsburg		89
				Cotati Public Utility District	Cotati		110
Mutual Water Companies							
Branger Mutual Water Company	Santa Rosa		7	Special Water Service Districts			
Broadmoor Acres Water Supply	Santa Rosa		19	Sonoma County Flood Control and Water Conservation District		(Sells at	whole- sale)
Carmet by the Sea Water Company	Bodega Bay		14				
East Austin Mutual Water Company	Cazadero		40				
Firecrest Mutual Water Company	Sebastopol		38	**Trinity County**			
Forest Home Park Water Supply	Forestville		135				
Graton Waterworks Company	Graton		32	Commercial Water Companies			
Holland Heights Mutual Water Company	Santa Rosa		100	Weaverville Water Works	Weaverville		358
Kelly Mutual Water Company	Sebastopol		40	County Waterworks Districts			
Lancaster Water Supply	Santa Rosa		8	Hayfork Water Works District No. 1	Hayfork		300
McChristian Water Supply	Bodega Bay		35				

WATER SERVICE AGENCIES, SAN FRANCISCO BAY AREA

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Alameda County			
Municipal Waterworks			
Hayward	Hayward		7,671
Pleasanton	Pleasanton		754
Commercial Water Companies			
California Water Service Company	Livermore		1,889
Citizens Utilities Company of California	Decoto Niles	40	1,401
Gallegos Waterworks	Mission San Jose		10
Mutual Water Companies			
Baumberg Well Water System	Hayward	30	40
Cerros Estrellados Water Company	Oakland	2	5
Highland Mutual Water Company	Hayward		242
Mohrland Mutual Water Association, Inc.	Hayward		80
Norris Canyon Mutual Water Company	Hayward		14
County Water Districts			
Alameda County Water District	Washington Township		2,500
Pleasanton Township County Water District	Pleasanton	500	77
Municipal Utility Districts			
East Bay Municipal Utility District	Oakland		187,000
Contra Costa County			
Municipal Waterworks			
Martinez	Martinez		3,310
Pittsburg	Pittsburg		3,500
Walnut Creek	Walnut Creek		939
Commercial Water Companies			
Bay Water Company	Pittsburg		1,555
California Water Service Company	Bay Point Concord Crockett Danville Martinez Oleum Port Costa Valona		15,658
Clyde Company	Clyde		115
Hercules Water Company	Pinole		645
Sobrante Water Company	Richmond		91
Webb Waterworks	Pittsburg		98
Mutual Water Companies			
Concord Boulevard Irrigation Group	Concord		60
Diablo Estates Water Corporation	Concord	10	
El Monte Water Association, Inc.	Concord	130	
Fifty-six Water Group	Concord	7	27
Oak Hill Irrigation Association	Martinez	18	15
County Water Districts			
Anderson Grove County Water District	Pacheco	6	
Contra Costa County Water District	Pittsburg	5,501	
Lafayette County Water District*	Lafayette		2,743
Orinda County Water District*	Orinda		2,134
Pleasant Hill County Water District*	Lafayette		1,063
San Miguel County Water District	Walnut Creek	240	40
Saranap County Water District*	Lafayette		1,340
Public Utility Districts			
Diablo Public Utility District	Danville	400	
Municipal Utility Districts			
East Bay Municipal Utility District	Oakland	(See Alameda County)	
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at wholesale)	

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Marin County			
Commercial Water Companies			
Inverness Park Water Company	Inverness Park		66
Inverness Water Works	Inverness		276
Muir Beach Company	Muir Beach		22
Olema Water System	Olema		31
Point Reyes Water Company	Point Reyes Station		130
Seahaven Water System	Inverness		7
Stinson Beach Water Company	Stinson Beach		237
Mutual Water Companies			
Hamilton Air Force Base	Ignacio	350	
County Water Districts			
North Marin County Water District	Novato		1,712
Public Utility Districts			
Bolinas Public Utility District	Bolinas		175
Bolinas Beach Public Utility District	Bolinas Beach		120
Municipal Water Districts			
Marin Municipal Water District	Fairfax Mill Valley San Anselmo San Rafael Sausalito, etc.		23,872
Napa County			
Municipal Waterworks			
Calistoga	Calistoga		580
Napa	Napa		5,435
St. Helena	St. Helena		923
Commercial Water Companies			
Hacienda Water Company	Napa		350
Lucchesi, F., Water System	Napa		47
Mutual Water Companies			
Bar 49 Ranch Water Supply	St. Helena	10	10
Bentley Home Sites Water Company	Calistoga		7
Pacific Union College Association	Angwin	90	100
Tucker Acres Water Company	Calistoga		7
County Water Districts			
Congress Valley Napa County Water District	Napa		19
Yountville Napa County Water District	Yountville		120
Special Water Service Districts			
Napa County Flood Control and Water Conservation District		(Sells surplus water outside district)	
San Francisco County			
Municipal Waterworks			
San Francisco	San Francisco		146,326
San Mateo County			
Municipal Waterworks			
Burlingame	Burlingame		
Daly City	Daly City		5,540
Hillsborough	Hillsborough		1,186
Millbrae	Millbrae		1,320
Redwood City	Redwood City		9,614
San Bruno	San Bruno	15	3,980
Commercial Water Companies			
Butano Land and Development Company	Butano Falls Tract		49
California Water Service Company	Atherton Broadmoor Menlo Park San Carlos San Mateo South San Francisco Woodside		30,288
Citizens Utilities Company of California	Montara Moss Beach		282

WATER SERVICE AGENCIES, SAN FRANCISCO BAY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
San Mateo County—Continued			
Commercial Water Companies—Continued			
Friendly Acres Water Company	Redwood City		1,015
San Carlos Manor Water System	San Carlos		120
Troutmere Utilities	La Honda		24
Visitacion City Water Company	Brisbane		427
Mutual Water Companies			
Bay View Mutual Water Company	Palo Alto	20	5
Brookside Water Company	Redwood City		37
Butano Canyon Mutual Water Company	Pescadero		49
Cuesta La Honda Guild	Redwood City		275
East Almond Cooperative Water Company	Palo Alto	12	10
Kings Mountain Park Water Company	Woodside		22
Ladera Water Company	Menlo Park		50
La Honda Vista Water Company No. 1	Redwood City		7
Loma Mar Mutual Water and Improvement Company	Loma Mar		12
Los Trancos Water Company	Menlo Park		91
Martins Beach Water Supply	Half Moon Bay		50
Marwel Water Company	Woodside	2	4
Millbrae Hills Mutual Water Company	Millbrae		14
O'Connor Tract Cooperative Water Company	Palo Alto	36	200
Olds Water Company	Redwood City		4
Palo Alto Park Mutual Water Company	Palo Alto		410
Rancho Canada Mutual Water Company	Redwood City		24
Searview Water Company, Inc.	Redwood City		3
Sky L'Onda Mutual Water Company, Inc.	Redwood City	70	124
Ware Acres Mutual Water Company	Woodside		13
Woodside Mutual Water Company	Woodside		30
County Water Districts			
Belmont County Water District	Belmont		1,774
Brisbane County Water District	Brisbane		650
Coastside County Water District	El Granada Half Moon Bay		675
North Coast County Water District	Sharp Park		1,800
County Waterworks Districts			
San Mateo County Waterworks District No. 1 (Ravenswood)	Palo Alto	50	528
San Mateo County Waterworks District No. 2 (East Palo Alto)	Palo Alto	50	913
San Mateo County Waterworks District No. 3 (Palomar Park)	Palo Alto		60
Municipal Improvement Districts and County Maintenance Districts			
Willow Road Water Maintenance District	Palo Alto		3,700
Public Utility Districts			
Diamond Public Utility District	San Francisco		625
Millbrae Public Utility District	Millbrae		267
Santa Clara County			
Municipal Waterworks			
Palo Alto	Palo Alto		11,575
Mountain View	Mountain View		2,832
Santa Clara	Santa Clara		3,157
Sunnyvale	Sunnyvale		3,250
Commercial Water Companies			
Agnew Water Works	Agnew		92
Aldercroft Heights Company, Inc.	Los Gatos		110
Almaden Water Company	Los Gatos	400	
Blacks Almaden Water System	Almaden		100
California Water Service Company	Los Altos		11,026
Campbell Water Company	Campbell	140	1,611
Criswell Water System	Los Gatos		10
Peninsula Service Corporation	Mountain View		31
Puccetti Water System	Mountain View	2	5
Putnam, Tarrant, Estate of	Cupertino	579	
Ryan, Water System, H.	Alma		11
Santa Clara County—Continued			
Commercial Water Companies—Continued			
San Jose Water Works	San Jose Campbell Los Gatos Saratoga		49,791
Santa Teresa Water Service	San Jose		30
Water Works of Monte Vista, Ltd.	Sunnyvale	130	718
Mutual Water Companies			
Berryessa Water Company	San Jose		7
Blanco Rancho Water Company	Los Altos		42
Briscoe-Emery Water Company	San Jose		27
Chemeketa Park Mutual Water Company	Los Gatos		151
Hamilton Water Company	Sunnyvale	138	----
Holy City Brotherhood	Holy City	20	12
Kirk Ditch	Campbell	1,210	----
Laco Mutual Water Company	Los Altos		15
Lake Canyon Mutual Water Company	Los Gatos		60
Lyndale Knolls Mutual Water Company	Los Altos		9
Melody Woods Water Company	Holy City		19
Oak Hill Mutual Water Company	Palo Alto		12
Oaknoll Water System	Mountain View		10
Rancho Water Trust	San Jose		20
Redwood Mutual Water Company, Inc.	Redwood Estates		290
Robleda Water Association	Los Altos		28
Rolling Hills Mutual Water Company	Cupertino		2
Saratoga Heights Mutual Water Company	Saratoga		5
Spinsk Water System	Los Altos	100	900
University Park Improvement Association	Mountain View		78
County Water Districts			
Milpitas County Water District	Milpitas		----
Special Water Service Districts			
Santa Clara County Flood Control and Water Conservation District		(Sells surplus water outside district)	
Solano County			
Municipal Waterworks			
Fairfield	Fairfield		1,031
Suisun	Suisun		775
Vallejo	Vallejo		13,000
Commercial Water Companies			
California-Pacific Utilities Company	Benicia		1,600
Irrigation Districts			
Solano Irrigation District	Fairfield	(See Table 5)	
Reclamation Districts			
Reclamation District 1607	Collinsville	2,461	----
Special Water Service Districts			
Solano County Flood Control and Water Conservation District		(Sells at wholesale)	
United States Bureau of Reclamation Projects			
Solano Project		(Sells at wholesale)	
Sonoma County			
City Waterworks Municipally Owned			
Sonoma	Sonoma		840
Privately Owned Water Companies			
California Water Service Compnay	Petaluma		4,300
Donaghy, Water Company	Glen Ellen		64
Glen Ellen Waterworks	Glen Ellen		210
Penngrove Water Company	Penngrove		70
Sonoma Water and Irrigation Company	Sonoma Vista Boyes Springs		1,071
Special Water Service Districts			
Sonoma County Flood Control and Water Conservation District		(Sells at wholesale)	

* Operated as part of the East Bay Municipal Utility District.

WATER SERVICE AGENCIES, CENTRAL COASTAL AREA

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Monterey County			
Municipal Waterworks			
Gonzales	Gonzales		357
Greenfield	Greenfield		375
Soledad	Soledad		482
Commercial Water Companies			
Alco Water Service	Alisal		2,134
Alisal Heights Water Company	Salinas	60	256
Ambler Park Water Utility	Ambler Park		70
Arroyo Seco Water Company	Soledad		53
Baird Water Company	Salinas	60	290
Bolsa Knolls Water Company	Salinas		114
California Water and Telephone Company	Carmel, Carmel Highlands, Monterey, Pacific Grove		15,615
Chualar Water Works	Chualar		66
East Monterey Water Service	Monterey		1,675
Fruitland Water Company	Watsonville	5	16
Los Lomas Water Company	Watsonville	110	145
Pacific Gas and Electric Company	King City, Salinas		762
Rancho Del Monte Water Company	Carmel		49
Mutual Water Companies			
Acacia Park Water and Improvement Association	Salinas		165
Aneste Water Supply	Salinas		10
Cassenelli Water Supply	Soledad	120	
Castroville Subdivision Water Supply	Castroville		19
Chetmore Acres Water Association	Watsonville	50	6
Clark Colony Water Company	Greenfield	3,600	
Coastlands Mutual Water Company	Carmel		20
Del Monte Ice Company	Castroville		5
Del Monte Water Company	Salinas		19
Fort Romie Water Company	Soledad	220	
Gabilan Water Company	Salinas		55
Laguna Seca Water Company, Inc.	Salinas		9
Larson Water Supply	San Lucas		15
McKanna Water Supply	Bradley		2
Mountain Springs Water Company			9
Orchard Lane Water Association	Salinas		16
Partington Mutual Water Company	Monterey		8
Phillips Water Supply	Castroville		13
Pierri Water Supply	Castroville		6
Reliz Water Company	Greenfield		
Rizzo Mutual Water Company	Castroville		5
Roberti Water Supply	Castroville		15
Rolling Hills Ranchos Water Association	Salinas		60
Snyder and Biddle Water Supply	Castroville		10
Spreckels Sugar Company	Spreckels	8.020	200
Springfield Mutual Water Company	Castroville		3
Tierra Verde Mutual Water Company	Salinas	30	17
Union Water Company of Greenfield	Greenfield	530	
Virginia Acres Water Company, Inc.	Salinas	12	
West Side Water Company of Greenfield	Greenfield	427	
White Tract Water Company	Salinas		14
Wildwood Water Company	Salinas		8
San Benito County			
Municipal Waterworks			
Hollister	Hollister		1,900
San Juan Bautista	San Juan Bautista		322
Commercial Water Companies			
Tres Pinos Water System	Tres Pinos		40
Mutual Water Companies			
Hepsedam Mutual Water Company	Hollister		35
San Justo Mutual Water Company	Hollister		11
Irrigation Districts			
Hollister Irrigation District	Hollister	17,500	
San Luis Obispo County			
Municipal Waterworks			
Arroyo Grande	Arroyo Grande		1,004
Paso Robles	Paso Robles		1,671
Pismo Beach	Pismo Beach		945
San Luis Obispo	San Luis Obispo		5,000
Commercial Water Companies			
Avila Water Company	Avila		150
Oceano Water Company	Oceano		78
Mutual Water Companies			
Atascadero Mutual Water Company	Atascadero		1,280
Branch's Mill Water Company	Arroyo Grande	200	
Cambria Pines Service Corporation	Cambria		410
Garden Farms Mutual Water Company	Atascadero		54
Green River Mutual Water Company	Paso Robles		47
Grieb-Taylor Ditch Company	Arroyo Grande	110	
McNeill Pump Company	Arroyo Grande	38	
Morro Rock Mutual Water Company	Cayucos		138
Paso Robles Beach Water Association	Cayucos		280
County Water Districts			
Grover City County Water District	Grover		750
County Waterworks Districts			
San Luis Obispo County Waterworks District No. 1 (San Miguel)	San Miguel		475
San Luis Obispo County Waterworks District No. 2 (Morro Bay)	Morro Bay		1,075
San Luis Obispo County Waterworks District No. 4 (Morro Bay)	Morro Bay		480
San Luis Obispo County Waterworks District No. 5 (Templeton)	Templeton		189
San Luis Obispo County Waterworks District No. 6 (Santa Margarita)	Santa Margarita		157
San Luis Obispo County Waterworks District No. 9 (Baywood)	Morro Bay		145
Santa Barbara County			
Municipal Waterworks			
Lompoc	Lompoc		1,406
Santa Barbara	Santa Barbara		13,270
Santa Maria	Santa Maria		3,924
Commercial Water Companies			
Campodonico Water Works	Guadalupe		574
Carpinteria Water Company, Inc.	Carpinteria	10	1,060
Casitas Road Water Company	Carpinteria	225	
Evergreen Service Company	Santa Maria		4
Mayer Tract Waterworks	Santa Maria		143
Ocean Oaks Water Company	Carpinteria		10
Orcutt Town Water Company	Orcutt		348
Solvang Water Works	Solvang		306
Toro Canyon Company, Inc.	Summerland		168
Mutual Water Companies			
Anderson Water Supply	Santa Ynez		16
Betteravia Water Supply	Betteravia	7,000	66
Carneros Water Company	Goleta	564	16
Cathedral Oaks Mutual Water Company	Santa Barbara	90	3
Dow Tract No. 1	Goleta	5	56
Dow Subdivision Water Company	Goleta		40
Erickson Subdivision Association	Santa Barbara		15
Gobernador Land and Water Company	Carpinteria	500	
Hyland Mutual Water Company	Santa Barbara		75
Ivydene Mutual Water Company	Montecito		18
La Cumbre Mutual Water Company	Santa Barbara	550	369
Las Positas Mutual Water Company	Santa Barbara		44
Mesa Associates Mutual Water Company	Carpinteria	72	7
Miramar Addition Improvement Company	Santa Barbara		15

WATER SERVICE AGENCIES, CENTRAL COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Santa Barbara County—Continued			
Mutual Water Companies—continued			
Montecito Creek Water Company	Santa Barbara		55
More Mesa Mutual Water Company	Santa Barbara	109	6
Newlove Water Company	Santa Maria	60	75
Painted Cave Mutual Water Company	Santa Barbara		33
Paradise Improvement Association	Santa Barbara		50
Patterson Road Mutual Water Company	Orcutt		16
Ranchoil Mutual Water Company	Cuyama	14	8
Rancho Sueno Mutual Water Company	Santa Barbara	56	93
Rincon Del Mar Mutual Water Company	Carpinteria		19
Rosario Park Water District	Santa Barbara		18
Riven Rock Mutual Water Company	Santa Barbara		6
Santa Maria Air Base Water Supply	Santa Maria		110
Serena Mutual Water Company	Santa Barbara	3	17
San Marcos Trout Club	Santa Barbara		33
Shepard Mesa Mutual Water Company	Carpinteria	155	15
Sunset Road Mutual Water Company	Santa Barbara	3	31
Sykes Water Supply	Santa Barbara		50
Terrace Mutual Water Company	Santa Barbara		50
Todmorden Mutual Water Company	Goleta	23	11
County Water Districts			
Carpinteria County Water District	Carpinteria	4,700	
Goleta County Water District	Goleta	16,000	1,000
Montecito County Water District	Santa Barbara	2,325	1,422
Summerland County Water District	Summerland		145
County Waterworks Districts			
Santa Barbara County Waterworks District No. 1	Buellton		105
Municipal Improvement Districts and County Maintenance Districts			
Solvang Municipal Improvement District	Solvang		371
Special Water Service Districts			
Santa Barbara County Water Agency		(Sells at	wholesale)
United States Bureau of Reclamation Projects			
Cachuma Project		(Sells at	wholesale)
Santa Clara County			
Municipal Waterworks			
Gilroy	Gilroy		1,442
Morgan Hill	Morgan Hill		705
Commercial Water Companies			
Mecchi Water Company	Morgan Hill		25
San Martin Water Works	San Martin		96
Mutual Water Companies			
Carpignano, James	San Martin		45
Cox, Agnes, Water Supply	Los Gatos	(See Santa	Cruz County)
Special Water Service Districts			
Santa Clara County Flood Control and Water Conservation District		(Sells surplus	water outside district)
Santa Cruz County			
Municipal Waterworks			
Santa Cruz	Santa Cruz	1,200	11,100
Watsonville	Watsonville		5,861
Commercial Water Companies			
Beltz Water System	Twin Lakes		757
Ben Lomond Redwood Park Water Company	Ben Lomond		115
Big Basin Water Company	Boulder Creek		45

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Santa Cruz County—Continued			
Commercial Water Companies—continued			
Citizens Utilities Company of California	Ben Lomond, Boulder Creek, Brookdale		2,138
Felton Water Company	Felton		711
Forest Glen Water Company	Aptos		35
La Selva Beach Water Company	La Selva Beach		193
Monterey Bay Water Company	Aptos, Capitola, Rio del Mar, Seacliff, Soquel		3,076
Riverside Grove Water Company, Inc.	Riverside Grove	5	98
Zayante Water Company	Zayante		167
Mutual Water Companies			
Assemblies of God	Santa Cruz		15
Bauer Water Company	Felton		30
Beulah Park Mutual Water Company	Santa Cruz		14
Big Redwood Park Mutual Water Company	Felton		24
Bracken Brae Corporation	Boulder Creek		25
California Conference of the Free Methodist Church			6
Camp Evers Store Water Supply	Santa Cruz	1	12
Cathedral Woods Mutual Water Company	Soquel	25	7
Cox, Agnes, Water Supply	Los Gatos		11
Davenport Water Supply	Davenport		80
Duffield Acres Water Supply	Watsonville	35	27
Forest Lakes Mutual Water Company	Felton		132
Forest Springs Mutual Water Company	Boulder Creek		108
Gold Gulch Mutual Water Company			27
Highland Park Water Service	Watsonville		12
Larita Woods Mutual Water Company, Inc.	Felton		30
Laurel Community League, Inc.	Laurel		27
Lompico Cooperative Water Association	Felton	640	238
Love Creek Heights Mutual Water Association	Ben Lomond		2
Manana Woods Mutual Water Company	Santa Cruz		20
Mountain Springs Water Service	Ben Lomond		11
Mount Hermon Association	Mount Hermon		432
New Freedom Mutual Water System	Watsonville		95
Olympia Mutual Water Company	Olympia		30
Paradise Park Masonic Club	Santa Cruz		375
Ramona Woods Mutual Water Company	Boulder Creek		23
San Lorenzo River Park Mutual Water Company	Boulder Creek		79
San Lorenzo Woods Mutual Water Company	Boulder Creek		47
Santa Hacienda Mutual Water Company	Santa Cruz	20	30
Sunset Beach Mutual Water Company	Watsonville		30
Terrace View Water Company	Santa Cruz		5
Vine Hill Mutual Water and Improvement Company	Santa Cruz		5
County Water Districts			
Central Santa Cruz County Water District	Aptos		24
San Lorenzo Valley County Water District	Boulder Creek, etc.		
County Waterworks Districts			
Santa Cruz County Waterworks District No. 1	Davenport		75
Special Water Service Districts			
Santa Cruz County Flood Control and Water Conservation District		(Sells at	wholesale)

WATER SERVICE AGENCIES, SOUTH COASTAL AREA

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Los Angeles County			
Municipal Waterworks			
Alhambra	Alhambra		15,042
Arcadia	Arcadia		8,964
Avalon	Avalon		1,000
Azusa	Azusa		3,236
Beverly Hills	Beverly Hills		9,577
Burbank	Burbank		21,991
Compton	Compton		9,846
Covina	Covina		2,010
El Monte	El Monte		2,364
El Segundo	El Segundo		2,522
Glendale	Glendale		25,448
Glendora	Glendora		1,610
Hawthorne	Hawthorne		5,663
Huntington Park	Huntington Park		6,026
Inglewood	Inglewood		12,850
La Verne	La Verne		1,230
Long Beach	Long Beach		56,846
Los Angeles	Los Angeles		421,229
Lynwood	Lynwood		8,525
Manhattan Beach	Manhattan Beach		7,194
Monrovia	Monrovia		6,779
Monterey Park	Monterey Park		7,296
Pasadena	Pasadena		36,609
Pomona	Pomona		10,417
San Fernando	San Fernando		3,699
Santa Monica	Santa Monica		15,687
Sierra Madre	Sierra Madre		2,484
Signal Hill	Signal Hill		1,387
South Gate	South Gate		12,721
South Pasadena	South Pasadena		4,839
Torrance	Torrance		5,832
Vernon	Vernon		652
Whittier	Whittier		8,602
Commercial Water Companies			
Azusa Valley Water Company	Covina, West Covina		2,200
Berlu Water Company	Bellflower		384
Bouquet Canyon Water Company	Saugus		55
California Michigan Land and Water Company	Lamanda Park, East Pasadena	400	1,433
California Water Service Company	East Los Angeles, Eastmont, Hermosa Beach, Redondo Beach, Torrance		38,953
California Water and Telephone Company	Azusa, El Monte, Rosemead, San Gabriel, San Marino	56	10,687
Central Gardens Water Company	South Gate, Lynwood		967
Coast Water Company	Bell Gardens	23	932
Conservative Water Company	Watts		8,667
Dominguez Water Corporation	Redondo Beach, Wilmington	2,000	5,600
Duarte Domestic Water Company	Duarte	800	4,000
East Gardena Water Company	Gardena	56	
East Pasadena Water Company, Ltd.	Lamanda Park, East Pasadena		131
Fairacres Water Company	North Long Beach		702
Ideal Petroleum Company	Bellflower		42
Investment Water Corporation, Ltd.	Los Angeles		5,013
Junior Water Company, Inc.	Norwalk		1,145
Lakewood Water and Power Company	Lakewood		19,261
La Mirada Water Company	La Mirada		12
Malibu Water Company	Rancho Topanga Malibu	60	987
Montebello Land and Water Company	Montebello	1,200	2,434
Narbonne Ranch Water Company No. 2	Lomita	360	575
Newhall Water Company	Newhall		818
Orchard Dale Service Company	Luitweiller, Orchard Dale	650	849

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Los Angeles County—Continued			
Municipal Waterworks—Continued			
Pacific Water Company	Burbank Tract, Hawaiian Gardens, Independence Square, Orangewood		1,646
Palos Verdes Water Company	Palos Verdes		2,037
Park Water Company	El Monte		24,326
Peerless Land and Water Company	Bellflower		500
Plunkett Water Company	Long Beach		22
Ranchito Water Company	Pico		198
San Dimas-Charter Oak Domestic Water Company	San Dimas, Charter Oak		1,480
San Gabriel Valley Water Company	Baldwin Park, El Monte, Whittier		27,453
Southern California Water Company	Culver City, Lennox and 25 others	1,070	69,491
Sparling Water Company	Topanga Canyon		545
Suburban Mutual Water Company	Norwalk		941
Suburban Water Systems	Covina, Downey, Glendora, Los Nietos, Puente, South Covina, West Covina, Whittier	1,550	7,587
Sunshine Water Company	Santa Fe Springs		1,150
Uehling Water Company, Inc.	Compton		1,280
Watson, Burl, Domestic Water Company	El Monte		493
Mutual Water Companies			
Adams, J. Q., Mutual Water Company	Puente	77	
Adams Ranch Mutual Water Company	Rosemead		97
Alta Canada Mutual Water Company	La Canada	50	4
Alvin Poore Water Service	El Monte		60
Amarillo Mutual Water Company	Garvey	171	380
Angelus Heights Water Company	La Crescenta	324	126
Annexation for Water, Inc.	La Crescenta, Montrose, Verdugo		6,000
Arroyo Ditch and Water Company	Downey	1,000	
Artesia Garden Water Association	Artesia	20	22
Artesia Ice Service	Artesia		30
Atlantic Boulevard Water Users Association	Long Beach		320
Avenue Line Water Association	Claremont	200	
Azusa Agricultural Water Company	Azusa	1,200	
Azusa Irrigating Company	Azusa	4,000	
Baker Cooperative Company	El Monte	7	20
Baker, I.F., Mutual Water Company	El Monte		18
Baldwin Park Water Company	Baldwin Park	135	
Banta Ditch Association	Whittier		
Base Line Water Company	La Verne	402	
Baughman Water Company	Claremont	1,001	
B-B Water Company	Puente	87	
Beck Tract Mutual Water System	Artesia		35
Bellflower Home Garden Water Company	Bellflower	120	250
Bellflower Water Company	Bellflower	195	1,606
Belvedere Mutual Water Company	Redondo Beach	3	112
Ben Sher Mutual Water Company, Inc.	Mint Canyon	300	43
Berggren-Robinson-Gagliaro Water Company	Puente	50	1
Beverly Acres Mutual Water Users Association	Whittier		75
B.F.S. Mutual Water Company	Whittier	200	
Bigby Townsite Water Company	Bellflower		178
Big Rock Beach Water Company	Malibu	10	101
Blue Ribbon Community Water Company	El Monte		105
Bonita Water Company	Claremont	160	

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Los Angeles County—Continued			
Mutual Water Companies—Continued			
Bonnie Brae Water Company	Claremont	190	
Botello Water Company	San Dimas	110	
Boulder Water Company	Claremont	300	
Boulevard Water Company No. 2	Baldwin Park	50	
Briggs Terrace Mutual Water Company	La Crescenta		30
California Domestic Water Company	Whittier	4,700	330
Canon Water Company of Pomona	Pomona	3,100	
Cantrill Mutual Water Company	El Monte		58
Canyon View Water Company	Baldwin Park	250	
Cassel Water Company	Covina	180	
Castaic Mutual Water Company	Castaic	200	75
Cate Ditch Company	Pico	300	
C and C Mutual Water Company	Baldwin Park	140	
Cedar Avenue Mutual Water Company, Inc.	El Monte		65
Center City Water Company	Paramount		125
Century Center Mutual Water Association	Clearwater		300
Century City Mutual Water Company	Hollydale		78
Cerritos Park Mutual Water Company	Bellflower		125
Cerro del Oro Water Company	La Verne	80	
Chatsworth Lake Mutual Water Corporation	Chatsworth		100
Cherryvale Water Users Association	Long Beach		28
Chrisco Mutual Water Association	Mint Canyon		48
Christian Acres Mutual Water Company	Hawaiian Gardens		127
Cienega Springs Water Company	Glendora	5	3
Citrus Grove Heights Water Company	Whittier	330	150
City Farms Mutual Water Company	Artesia	21	46
Claremont Basin Mutual Water Company	Claremont	1,000	
Claremont Cooperative Water Company	Claremont	600	60
Claremont Heights Irrigation Company	Claremont	300	66
Colima Tract Water Company	Whittier	500	
College Way Mutual Domestic Company	La Verne		8
Columbia Land and Water Company	San Dimas	510	
Community Water Supply	Norwalk		9
Comstock Water Company	Puente	150	2
Connemara Mutual Water Company	Azusa	55	10
Contract Water Company of Azusa	Azusa	1,200	
Cook Tract Water Company	Paramount		66
Corona Del Malibu	Malibu		2
Corral Canyon Mutual Water Company	Malibu		20
Covina Highlands Water Company	Covina	60	19
Covina Irrigating Company	Covina	3,500	
Crescenta Mutual Water Company	Montrose		2,960
Cross Water Company	Puente	1,000	450
Crystal Mutual Water Company	Whittier		318
Deerpath Mutual Water Company	Santa Monica		84
Del Monte Irrigation Company	Pomona	1,800	
Del Rio Mutual Water Company	El Monte		169
Didier Farms Mutual Water Company	Puente	155	20
Downey Valley Water Company	Downey	25	53
Dreher, E. L., Agent	Claremont	170	
Duarte Mutual Water Company	Duarte		
Durward Well Company	La Verne	74	
East End Irrigation Company	Pomona	175	
East Gardena Water Company	Gardena	250	
Edgemont Water Company	La Verne	40	
El Camino Water Company	Claremont	300	
El Campo Mutual Water Company	San Marino		54
El Monte Community Association	El Monte		130
El Segundo Land and Improvement Company	El Segundo	15	1
Eureka Water Company	Claremont	70	1
Fairview Mutual Water Company	Claremont	188	
Farm Mutual Water Company	El Monte		222
Fickewirth Mutual Water Company, Ltd.	Puente	78	
Flintridge Heights Mutual Water Company	Glendale		4
Francisquito Water Company	Puente	90	
Los Angeles County—Continued			
Mutual Water Companies—Continued			
Franklin Avenue Water Company, Inc.	Pomona	66	
Fruit Street Water Company	La Verne	120	
Gardena Water Supply Company	Gardena	125	
Giano Mutual Water Company	Puente		15
Glendora Independent Water Company	Glendora	1,500	140
Glendora Irrigating Company	Glendora	2,500	250
Golden Poppy Park Water Trust	Compton		100
Grazide Rancho Mutual Water Company	Puente	300	25
Harrison Avenue Water Company	Claremont	375	
Haskin, Claire R., Water Company	Compton		33
Hemlock Mutual Water Company	El Monte		134
Hepner Water Company	Covina	100	
Herbert Mutual Water Company	El Monte	50	72
Hidden Hills Mutual Water Company	Calabasas		44
Highway Highlands Water Company	Glendale		1,002
Hilgartner Mutual Water Company	Vernon		6
H.J.S. Mutual Water Company	Compton		76
Hollenbeck Street Water Company	West Covina	320	19
Home Water Company	Compton		60
Howell Road Mutual Water Company	Puente	100	12
Indian Hill Water Company	Claremont	90	
Irrigation Company of Pomona	Pomona	1,000	
Jenkins Realty Mutual Water Company	Artesia		12
Jones-Yorba Mutual Water Company	La Verne	145	
Kingsley Tract Water Co., Ltd.	Pomona	350	93
Kinneloa Water Company	Pasadena		52
Kwis Mutual Water Company	Puente	183	185
La Grande Source Water Company	Puente	885	
Laguna Maywood Mutual Water Company No. 1	Maywood		56
La Habra Heights Mutual Water Company	La Habra	2,800	570
Lake Hughes Water Supply	Lake Hughes		175
Lambert Mutual Water Company	El Monte	20	60
La Merced Heights Land and Water Company	Montebello	300	
La Puente Cooperative Water Company	Covina	1,800	
Las Flores Mesas Water System	Malibu		19
Las Flores Water Company	Pasadena		1,057
Las Tunas Water Company, Ltd.	Malibu		50
La Verne Heights Water Association	La Verne		46
La Verne Mutual Water Company	La Verne	111	
La Verne Water Association	La Verne	900	62
Leffingwell Rancho Pipe Line Association	Whittier	309	
Lexington Boulevard Mutual Water Company	El Monte	10	28
Lincoln Avenue Water Company, Inc.	Pasadena	10	3,009
Live Oak Water Company	Pomona	100	
Loma Mutual Water Company	El Monte		5
Los Nietos Irrigation Company	Whittier	1,200	
Lowell Avenue Mutual Water Company	Los Angeles	42	26
Lowell Tract Water Company	Whittier	10	13
Lynwood Gardens Mutual Water Company	Lynwood		350
Lynwood Park Mutual Water Company	Compton		354
Maechtlen and Nusbickel	La Verne	200	
Main Avenue Mutual Water Company	Baldwin Park	40	
Malibu Lake Mountain Club, Ltd.	Agoura		100
Malibu Lakeside Mutual Water Company	Agoura		100
Malibu Mar Vista Mutual Water Company	Malibu		1
Maple Mutual Water Company	Bellflower		38
Maple Water Company	Puente		96
Maxson-Neely Water Company	Covina	15	
Maywood Mutual Water Company No. 1	Maywood		1,200
Maywood Mutual Water Company No. 2	Maywood		1,710

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Los Angeles County—Continued			
Mutual Water Companies—Continued			
Maywood Mutual Water Company No. 3	Maywood		1,830
McCauley Well Company, Ltd.	Pomona	90	
Meadows Mutual Water Company	Whittier		13
Mesa Mutual Water Company	Pasadena		23
Metcalf Mutual Water Company, Inc.	El Monte		9
Michigan Avenue Farms Mutual Water Company	Paramount		136
Midland Park Water Trust	Compton		104
Midway Gardens Mutual Association	Paramount	28	112
Mills Tract Water Company	La Verne	150	
Mint Canyon Village Water Company	Newhall	46	121
Mira Loma Mutual Water Company	Pasadena	90	89
Mission Gardens Mutual Water Company	Garvey		155
Moneta Water Company	Torrance	1,250	300
Mont Antonio Water Company	Claremont	400	
Monte Mutual Water Company, Inc.	El Monte		40
Monterey Acres Mutual Water Company, Inc.	Artesia		133
Monte Vista Pipe Line Association	Sunland	123	
Monte Vista Water Company	Pomona	400	
Mountain View Gardens Mutual Water Association	Long Beach		30
Mountain Water Company of La Crescenta	Glendale	1,200	2,200
Mount Wilson Hotel Company	Mount Wilson		7
Murphy Ranch Mutual Water Company	Whittier	650	286
Narbonne Ranch Water Company No. 3	Torrance	4	246
Neighbors Water Association	Compton		8
New Mint Water System	Newhall		59
North El Monte Water Company	El Monte	150	
North Gate Gardens Water Company	North Long Beach		150
North Long Beach Extension Water Company	North Long Beach		400
North Palomares Irrigation Company	Claremont	684	
North Side Water Company of Walnut	Walnut	750	
Old Baldy Water Company	La Verne	357	
Olivita Mutual Water Company	Inglewood		283
Omaha Water Company	Covina	230	
Orange Belt Water Company	Covina	25	
Orange Grove Tract Water Company	Pomona	300	320
Orchard Park Water Club, Inc.	Long Beach		125
Packard Mutual Water Company	Pomona		115
Packers Mutual Water Company	Los Angeles		10
Palomares Irrigation Company	Pomona	425	
Park Avenue Well Association	Pomona	104	
Park, Sherman and Taylor	Malibu		8
Pearson's Mutual Water Company	Covina	150	
Piedmont Heights Water Club	Long Beach		20
Pomona Ranch Water Company	Claremont	220	
Potrero Heights Water Company	San Gabriel	30	524
Property Owners Water System	Newhall		40
Puddingstone Water Company	La Verne	101	30
Purity Mutual Water Company	El Monte		99
Ramona Avenue Irrigation Company	Pomona	100	
Rancho Green Valley Water Company	Saugus		155
Rancho Mutual Water Company	Rolling Hills		289
Rancho Santa Gertrudes Mutual Water System	Downey	40	28
Reeves Tract Water Company	Bellflower		45
Richards Irrigation Company	Claremont	400	20
Richland Farms Water Company	Compton	203	315
Richwood Mutual Water Company	El Monte		135
Rincon Ditch Company	Whittier	527	
Riverwood Ranch Mutual Water Company	Los Angeles		25
Rowland and Foster Water Company	Puente	250	75
Rowland Manor Mutual Water Company	Walnut		102
Rubio Canon Land and Water Association	Altadena		2,370
Rurban Homes Mutual Water Company, Inc.	El Monte		132
San Dimas Land and Water Company	La Verne	340	
San Dimas Water Company	Covina	2,800	
Santa Catalina Island Company	Avalon		850
Santa Gertrudes Irrigation Company	Whittier	15	
Los Angeles County—Continued			
Mutual Water Companies—Continued			
Santa Gertrudes Water Company	Whittier	80	
Sepulveda, R. D., Estate	San Pedro	7	1
Simons Brick Company	Montebello	1	135
Somerset Mutual Water Company	Bellflower		2,600
Sorenson Mutual Water Association	Whittier		10
Southland Water Company	Norwalk		1,500
Standefer Ditch Company	Pico	400	
Stanton Water Company	Puente	60	
Sterling Mutual Water Company	El Monte		85
Studebaker Mutual Water Company	Norwalk		59
Sunny Slope Water Company	San Gabriel	990	4,569
Sunset Mutual Water Company	Puente	40	
Swan Ranch Water Company	Walnut	155	
Swenson Mutual Water Company	Baldwin Park	100	
Sylvia Park Mutual Water and Service Company	Topanga		35
Temple Avenue Mutual Water Company	Puente	200	1
Templeton Water System	El Monte		14
Topanga Beach Water Association	Santa Monica		172
Topanga Oaks Mutual Water Company	Topanga		50
Topanga Park Mutual Water Company, Inc.	Topanga		75
T P K & B Water Company	Puente	138	
Tract 180 Water Company	Bell		1,000
Tract 349 Mutual Water Company	Huntington Park	10	850
Tract 6192 Water Company	Whittier		72
Twin Lakes Park Company	Chatsworth		62
Upper Kagel Canyon Mutual Water Association	San Fernando		13
Valencia Heights Water Company	Covina	800	150
Valencia Water Company	Puente	310	16
Valencia Water Company	Covina	425	9
Valhalla Water Association	Tujunga		16
Valley View Mutual Water Company	Baldwin Park	40	500
Valley View Water Company	Claremont	175	
Valley Water Company	Pasadena		2,300
Val Verde Park Water Company	Saugus	1,080	214
Veteran Springs Mutual Water Company	Veteran Springs		44
Victoria Mutual Water Company	Puente	300	
Walnut Mutual Water Company	Walnut		21
Walnut Park Mutual Water Company	Huntington Park	640	2,872
Walnut Place Mutual Water Company No. 17	Baldwin Park		51
Walnut Place Mutual Water Company No. 36	Baldwin Park	12	30
Walnut Place Mutual Water Company No. 42	Baldwin Park	28	20
Weldon Canyon Cooperative Water Association No. 1	San Fernando		4
Werner Tract Mutual Water Company	Baldwin Park		200
West Coast Water Company	Rosemead	55	
West Gateway Mutual Water Company	Whittier		195
West Newhall Mutual Water Company	Newhall		45
Whittier Extension Mutual Water Company	Puente	2,200	176
Wood Mutual Water Company	El Monte		61
Woodland Mutual Water Company	El Monte	33	41
County Waterworks Districts			
Los Angeles County Waterworks District No. 1, (Woodcrest)	Los Angeles		2,121
Los Angeles County Waterworks District No. 2, (Norwalk)	Norwalk	5	964
Los Angeles County Waterworks District No. 5, (Belle-Vernon)	Compton		840
Los Angeles County Waterworks District No. 10, (Willowbrook)	Los Angeles	5	1,489
Los Angeles County Waterworks District No. 13, (Lomita)	Lomita	100	2,310
Los Angeles County Waterworks District No. 16, (Miramonte Park)	Los Angeles		1,215
Los Angeles County Waterworks District No. 21, (Kagel Canyon)	San Fernando		219
Los Angeles County Waterworks District No. 22, (Liberty Acres)	Hawthorne		3,159

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Los Angeles County—Continued			
Municipal Water Districts			
Foothill Municipal Water District	La Crescenta, etc.	14,000	20,250
Pomona Valley Municipal Water District	Pomona, etc.	8,500	------
Torrance Municipal Water District No. 1	Torrance	125	------
Torrance Municipal Water District No. 3	Torrance	2,000	7,800
West Basin Municipal Water District	Inglewood, etc.	(Sells at wholesale)	
County Water Districts			
Baldwin Park County Water District	Baldwin Park	------	5,100
Crescenta Valley County Water District	Glendale	2,400	3,900
Downey County Water District	Downey	------	7,500
La Puente Valley County Water District	Puente	440	------
Newhall County Water District	Newhall	------	------
Paramount County Water District	Paramount	------	1,721
Pico County Water District	Pico	------	4,150
San Gabriel County Water District	San Gabriel	2	7,125
Sativa Los Angeles County Water District	Compton	------	1,126
Val Verde County Water District	Saugus	------	186
Irrigation Districts			
La Canada Irrigation District	Pasadena	------	1,610
South Montebello Irrigation District	Montebello	190	1,525
Walnut Irrigation District	Downey	------	750
Metropolitan Water Districts			
Metropolitan Water District of Southern California	------	(Sells at wholesale)	
Orange County			
Municipal Waterworks			
Anaheim	Anaheim	------	4,764
Brea	Brea	------	1,350
Fullerton	Fullerton	------	4,808
La Habra	La Habra	------	2,000
Newport Beach	Newport Beach	------	6,800
Orange	Orange	------	3,541
San Clemente	San Clemente	------	1,100
Santa Ana	Santa Ana	------	15,418
Seal Beach	Seal Beach	------	1,035
Commercial Water Companies			
Clark Pumping Plant	Garden Grove	45	------
Dyke Water Company	Garden Grove	------	------
Jones Water Company	El Modena	------	391
Martinez, J., Water System	Garden Grove	------	91
Pacific Water Company	Barber City, New Westminster and 7 others	------	2,713
Park Lane Water Company	Garden Grove	------	46
San Juan Water Company	Laguna Beach	------	650
Southern California Water Company	Huntington Beach and 6 others	------	4,452
Sunset Land and Water Company	Sunset Beach	------	499
Tustin Water Works	Tustin	14	1,375
Mutual Water Companies			
Anaheim Eucalyptus Water Company	Placentia	740	------
Anaheim Union Water Company	Anaheim	8,500	------
Arovista Mutual Water Company	Brae	500	5
Atwood Water Company	Atwood	210	------
Benedict Water Company	Anaheim	101	------
Boulevard Gardens Water Company	Boulevard Gardens	6	107
Brookhurst Water Company	Anaheim	100	3
Capistrano Acres Mutual Water Company	San Juan Capistrano	415	------
Capistrano Heights Water Company	San Juan Capistrano	195	------
Capistrano Water Company	San Juan Capistrano	432	------
Catalina Street Pump Owners	Santa Ana	------	13
Cerritos Water Company	Anaheim	108	------

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Orange County—Continued			
Mutual Water Companies—Continued			
Citrus Water Association	Orange	------	26
Citrus Water Company	Santa Ana	157	------
Colonia Mutual Water Company	Anaheim	------	110
Dalewood Mutual Water Association	Garden Grove	------	77
Dawn Water Company	Orange	290	11
Diamond Park Mutual Water Company	Santa Ana	------	94
Eastside Water Association	Santa Ana	------	250
El Aguador Irrigation Company	Anaheim	62	8
El Camino Water Company	Fullerton	100	------
El Modena Mutual Irrigation Company	Santa Ana	400	50
El Toro Mutual Water Company No. 1	El Toro	300	------
Equitable Water Company	Anaheim	103	5
Fairview Farms Water Company	Santa Ana	409	------
Fardale Mutual Water Company	Anaheim	70	------
Fardale Pump Company	Anaheim	90	3
Frances Mutual Water Company	Tustin	1,227	------
Garden Grove Acres Mutual Water Company	Santa Ana	40	44
Garden Grove Irrigation Company No. 1	Garden Grove	160	------
Gay Street Water Association	Cypress	------	22
Goodwin Mutual Water Company	Placentia	52	4
Grandview Mutual Water Company	La Habra	120	------
Greenwald Mutual Water Company	Santa Ana	60	------
Hall, Hellis, and Bradford, and Holtz	Santa Ana	100	------
Hansen Water Company	Stanton	98	12
Harding Water Users	Anaheim	10	26
H and M Water Company	Stanton	------	9
Homewood Mutual Water Company	North Buena Park	------	498
Hualde Mutual Water Company	La Habra	350	------
Ideal Water Company	Anaheim	143	1
Katella Water Company	Anaheim	107	------
Kellogg Water Company	Anaheim	105	------
La Habra Water Company	La Habra	3,000	365
La Paz Mutual Water Company	Garden Grove	------	59
Lemon Heights Mutual Water Company	Tustin	275	------
Liberty Park Water Association	Huntington Beach	------	48
Loma Vista Mutual Water Company	Tustin	35	7
Lomita Land and Water Company	Seal Beach	300	1
Magnolia Mutual Water Company	Anaheim	75	12
Magnolia Pumping Plant	Anaheim	120	
Magnolia Union Water Association	Anaheim	120	------
Midway City Mutual Water Company	Midway City	------	165
Miller Manor Mutual Water Company	Orange	------	3
Mine Camp Water System	Orange	------	35
Miraflores Mutual Water Company	Anaheim	------	4
M.O.B. Mutual Water Company	Fullerton	200	------
Modjeska Service Company	Orange	------	106
Moore Mutual Water Company	Oceanview	36	60
Mutual Water Company of Goode Subdivision	Santa Ana	------	19
Mutual Water Company of Landsdown	Fullerton	80	220
Newhope Water Company	Santa Ana	20	6
North East Water Company	Anaheim	90	10
North Street Copartnership Pumping Plant	Anaheim	85	------
Nutwood Mutual Pumping Plant Association	Anaheim	120	3
Orange Avenue Water Company	Anaheim	71	2
Orange County Water Service Company	Anaheim	10	14
Orange Grove Water Company	Anaheim	119	------
Orange Magnolia Water Company	Buena Park	------	15
Orange Park Acres Mutual Water Company	Orange	800	200
Orangewood Water Company	Anaheim	70	4
P. A. Stanton Water Company	Anaheim	123	3
Palm Mutual Water Company	Anaheim	70	------
Panorama Heights Mutual Water Company	Orange	4	18
Parsons Mutual Water Company	Garden Grove	2	9
Paw Paw Mutual Irrigation Company	Fullerton	80	------
Peralta Hills Water Company	Olive	354	24
Pilot Water Company	Placentia	300	------

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Orange County—Continued			
Mutual Water Companies—Continued			
Placentia Mutual Water Company	Placentia	97	12
Red Hill Water Company	Tustin	1,085	
Richfield Mutual Water Company	Atwood	200	
Rio Vista Water Company	Anaheim	123	7
Romenya Drive Mutual Water Company, Inc.	Anaheim	87	6
Saamae Land and Water Company	Huntington Beach	60	2
San Juan Heights Water Company	San Juan Capistrano	80	4
Santa Ana Heights Water Company	Santa Ana	194	867
Santa Ana Street Water Company	Anaheim	144	8
Santa Ana Valley Irrigation Company	Orange	15,800	
Santiago Mutual Water Company	Orange	30	10
Savanna Mutual Water Corporation	Stanton	15	24
Schneider Water Company	Anaheim	25	7
Section Two Water Company	Anaheim	250	34
Section 13 Water Company	Anaheim	176	8
Seven Hills Mutual Water Company	Tustin	600	8
Shady Brook Water Company	Silverado		150
Silverado Mutual Water Company	Silverado		54
South Main Mutual Water Company, Inc.	Santa Ana		384
Southwestern Mutual Water Company, Inc.	Santa Ana		141
Stanky Pumping Plant	Anaheim	65	4
Sunny Hills Mutual Water Company	Fullerton	2,000	120
Sunset Land and Water Company	Seal Beach		505
Trabuco Oaks Mutual Water Company	Santa Ana		71
Trabuco Water Company	San Juan Capistrano	440	
Tract 868 Mutual Water Company	Stanton	20	48
Tract 1022 Mutual Water Company	Santa Ana	40	5
Tract 1052 Mutual Water Association	Garden Grove		98
Turner Mutual Water Company	Tustin	85	
Tustin Mutual Water Company	Tustin		
Tye Water Company	Anaheim	131	
Valencia Irrigation Company, Inc.	Anaheim	103	
Valencia Water Company	Anaheim	128	
Villa Park Mutual Water Company, Inc.	Orange	266	
Vista Del Rio Rancho Water Group	Anaheim	100	5
Walnut Canyon Mutual Water Company	Anaheim	250	
Webster Tract Water System	Anaheim		20
West Anaheim Water Company	Anaheim	360	4
Wilminedi Water Company	Anaheim	100	2
Yorba Irrigation Company	Yorba Linda	1,150	
Yorba Linda Water Company	Yorba Linda	2,540	530
County Water Districts			
Fairview County Water District	Costa Mesa		809
Laguna Beach County Water District	Laguna Beach		3,850
Orange County Water District No. 2	Buena Park		1,492
Orange County Water District No. 3	Garden Grove		2,906
Orange County Water District No. 4	San Juan Capistrano		220
Orange County Water District No. 5	Westminster		407
Orange County Water District No. 7	Anaheim		193
Orange County Water District No. 8	El Modena		116
South Coast County Water District	South Laguna		970
Irrigation Districts			
Carpenter Irrigation District	Orange	1,200	
Newport Heights Irrigation District	Newport Beach	60	2,397
Newport Mesa Irrigation District	Newport Beach	50	434
Serrano Irrigation District	Orange	1,316	
Municipal Water Districts			
Coastal Municipal Water District	Laguna Beach, etc.	(Sells at	wholesale)
Orange County Municipal Water District	Placentia, etc.	(Sells at	wholesale)
Metropolitan Water Districts			
Metropolitan Water District of Southern California		(Sells at	wholesale)

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Riverside County			
Municipal Waterworks			
Elsinore	Elsinore		917
Perris	Perris		620
Riverside	Riverside		14,757
San Jacinto	San Jacinto		770
Commercial Water Companies			
Anza Water Company	Arlington	120	390
Citizens Domestic Water Company	Arlington, La Sierra, La Sierra Heights		1,950
Corona City Water Company	Corona		2,899
Good Hope Water Company	Perris		14
Idyllwild Water Company	Idyllwild		521
Inter-County Water Company	Crestmore		70
Jurupa Heights Water Company	Sparrland		450
Lake Hemet Water Company	Hemet		2,490
Mission Water Company	West Riverside		651
Romoland Water System	Romoland		150
Rubidoux Vista Water System	West Riverside		183
Sunny Slope Heights Water Company	West Riverside		578
West Riverside Canal Company	Riverside	7,200	
Mutual Water Companies			
Agua Mansa Water Company	Riverside	620	
Alamo Water Company	Riverside	250	
Alta Mesa Mutual Water Company	Arlington	160	
Anza Water Company	Arlington	750	250
Aqua Copia Mutual Water Company	Mira Loma	1,200	3
Arlington Mutual Water Company	Arlington	1,200	
Babtiste Mutual Water Company	Hemet	188	
Billick Mutual Water Company	Hemet	158	
Bonita Vista Mutual Water Company		78	9
Box Springs Mutual Water Company	Edgemont	480	420
Brownlands Mutual Water Company	Lakeview	1,800	
Cajalco Mutual Water Company	Corona	200	50
Cherry Valley Mutual Water Company	Beaumont		6
Clayton Mutual Water Company	Clayton		34
Clearview Mutual Water Company	Riverside	7	40
Clear Water Company, Inc.	Riverside	260	
Corona Heights Water Company	Corona	300	
Corona Mesa Water Company	Corona		4
Coronita Mutual Water Company	Corona		15
Crestmore Heights Mutual Water Company	Riverside		47
East Riverside Water Company	Riverside	3,350	
Edgemont Gardens Mutual Water Company	Sunnymead	430	450
Elsinore Valley Mutual Water Company	Elsinore	110	35
Eryl Water Company	Hemet	165	
Fairview Land and Water Company	Hemet	200	
Fairview Pumping Plant	Hemet	60	
Fairway Mutual Water Corporation	San Jacinto		38
Felspar Gardens Water Company	Riverside		41
Fern Valley Mutual Water Company	Idyllwild		274
Foothill Mutual Water Company	Hemet	240	
Fort Fremont Mutual Water Company	Riverside		212
Fruitvale Mutual Water Company	San Jacinto	5,368	
Gage Canal Company	Riverside	6,394	
Girard Street Mutual Water Company	Hemet	125	
Glass-Gilmore Mutual Water Company	Perris		4
Glen Eyrie Heights Mutual Water Company	Beaumont	310	10
Grand Avenue Mutual Water Company	Elsinore	6	23
Grand View Mutual Water Company	Beaumont	44	39
Hannon Mutual Water Company	Beaumont	60	12
Highline Mutual Water Company	Hemet	175	
Home Gardens Water Company	Corona		437
Idyllmont Mutual Water Company	Idyllwild		3
Jewell and Clemens Pumping Plant	Hemet	145	
Jurupa Ditch Company	Riverside	600	
Jurupa Water Company	Riverside	988	
Kilmeny Lot Owners Water Association	Elsinore	12	75
La Cadena Mutual Water Company	Riverside		27
Laguna Mutual Water Company	Hemet	200	

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Riverside County—Continued			
Mutual Water Companies—Continued			
Lakeview Mutual Water Company	Elsinore		91
Landowners Mutual Water Company	Elsinore		56
La Sierra Water Company	Riverside	1,500	
Lemona Heights Water Company	Riverside	190	
Lincoln Heights Pumping Company	Riverside	255	
Lincoln Heights Water Company	Riverside		
Little Lake Mutual Water Company	Hemet	355	
L.T.J. Water Company	Hemet	300	
Madison Park Pump Association	Riverside	70	
Mayberry Avenue Mutual Water Company	Hemet	65	
Meridian Mutual Water Company	Hemet	200	
Merryman Water Company	Hemet	297	
Midway Mutual Water Company	Hemet	175	
Mockingbird Pumping Company	Riverside		150
Monte Rue Acres Mutual Water Company	Riverside		48
Moreno Mutual Irrigation Company	Moreno	1,000	
Moreno Water Company	Moreno	350	
Mountain Mutual Water Company	Hemet		8
Mutual Water Company of Glen Avon Heights	Riverside	4,000	450
Nuevo Water Company	Perris	2,000	220
Orange Heights Water Company	Norco	2,500	800
Park Hill Mutual Water Company	Hemet	200	
Perris Mutual Water Company	Perris	130	
Perris Valley Irrigation Company	Perris	3,200	56
Pine Cove Mutual Water Company	Idyllwild		149
Plantation Mutual Pumping Company	Corona	750	
Prado Basin Water Company	Corona	120	
Prenda Pumping Company	Riverside		165
Ramona Mutual Water Company	Hemet	90	
Riverside Highlands Water Company	Highgrove	2,000	225
Riverside Water Company	Riverside	8,700	
Rivino Water Company	Riverside	186	
Salazar Water Company	Riverside	200	
Santa Ana River Water Company	Mira Loma	1,351	640
Santa Fe Mutual Water Company	Hemet	160	
Soboba Mutual Water Company	Hemet	120	
Soboba Water Company	Hemet	210	
South Elsinore Mutual Water Company	Elsinore	1,000	265
South Valley Mutual Water Company	Hemet	275	
Sunnymead Mutual Water Company	Sunnymead	168	54
Tahquitz Mutual Water Company	Hemet	255	
Temescal Water Company	Corona	5,000	
Trujillo Water Company	Riverside	200	
Twin Buttes Water Company	Arlington	1,500	
Valencia Mutual Water Company	Riverside	83	7
Walcot Mutual Water Company	Hemet	150	
Welles Mutual Water Company	Hemet	115	
West End Irrigation Company	Elsinore	75	1
West Riverside Mutual Water Company of Belltown	Riverside	40	96
West Riverside 350-Inch Water Company	Riverside	1,400	
Whiffing Pumping Company	Arlington Heights	75	
Wineland Vineyards Mutual Water Company	Mira Loma	40	82
Yale Mutual Water Company	Hemet	200	
Irrigation Districts			
Beaumont Irrigation District	Beaumont	2,101	1,817
Municipal Water Districts			
Eastern Municipal Water District	Hemet, etc.		
Western Municipal Water District	Riverside, etc.		
Metropolitan Water Districts			
Metropolitan Water District of Southern California		(Sells at	wholesale)
San Bernardino County			
Municipal Waterworks			
Chino	Chino		1,671
Colton	Colton		4,181
Ontario	Ontario		7,783
San Bernardino County—Continued			
Municipal Waterworks—Continued			
Redlands	Redlands		6,655
Rialto	Rialto		1,152
San Bernardino	San Bernardino		20,699
Upland	Upland		2,794
Commercial Water Companies			
Big Bear Pines Water Company	Big Bear Lake		248
Crestmore Village Water Company	Crestmore		165
Delmann Water Company	San Bernardino		17
East Highlands Domestic Water Company	East Highlands		110
East San Bernardino Water Company	East San Bernardino		178
Estates Water Company, Ltd.	Upland	25	248
Fontana Ranchos Water Company	Fontana		83
Godfrey Heights Water Company	Highgrove		12
Inter-County Water Company	Crestmore	(See Riverside	County)
Meadowbrook Water Association	Lake Arrowhead	(See Table 6)	
Mentone Domestic Water Company	Mentone	10	170
North Cucamonga Water Company	Cucamonga		289
Pacific Water Company	Rimforest		36
Park Water Company	Bloomington Chino Crestmore		
Peterson Water Company, Inc.	Loma Linda	18	135
Pioneer Gardens Water Company	San Bernardino		1,512
Pomona Valley Water Company	Chino		191
Running Springs Forest Water Company	San Bernardino		9
San Bernardino Water Utilities Corporation	Verdemont	150	514
Southern California Water Company	Big Bear Lake Bloomington Highland		3,051
Yucaipa Domestic Water Company	Redlands Yucaipa		457
Mutual Water Companies			
Alta Loma Domestic Water Company	Alta Loma		187
Alta Loma Mutual Water Company	Cucamonga	123	
Anderson Mutual Wells Company, Inc.	Highland	90	
Archibald Avenue Water Company	Cucamonga	280	
Arena Mutual Water Association	Ontario	325	
Arrow Route Water Company	Cucamonga	210	
Arroyo Verde Mutual Water Company	San Bernardino		101
Banyan Heights Water Company	Upland	135	
Barnhill Mutual Water Company	Colton	160	
Base Mutual Water Company	Highland	10	62
Bear Valley Extension Water and Pipe Line Company	Bryn Mawr	1,200	
Bear Valley Mutual Water Company	Redlands	7,600	
Beaumont-Yucaipa Water Conservation Assocaition	Yucaipa	200	
Big Bear City Mutual Service Company	Big Bear City	20	707
Big Pine Tract Improvement and Water Association, Inc.	Forest Home		135
Blue Mountain Mutual Water Company	Colton		12
Bon View Mutual Water Association	Ontario	220	
Boulder Water Company	Claremont	150	
Brookings Pipe Line Mutual Water Company	Fredalba		19
Bryn Mawr Mutual Water Company	Redlands	288	
Canyon Ridge Water Company	Upland	180	
Cardiff Farms Mutual Water Company	San Bernardino	48	168
Cedarpines Park Mutual Water Company	Cedarpines		470
Century Water Company	Chino	80	9
Chino District No. 1 Water Company	Chino	68	
Chino Water Company, The	Ontario	1,000	
Church Street Mutual Well Company	Redlands	70	

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
San Bernardino County—Continued			
Mutual Water Companies—Continued			
Citizens Land and Water Company of Bloomington	Bloomington	4,774	
Citrus Water Company	Cucamonga	105	4
City Creek Water Company	Highland	400	
Colton Avenue Water Company	Redlands	50	
Community Water Association of Highland	Highland		41
Conejo Ranchos Mutual Water Company	San Bernardino		71
Corwin Well Company	Highland	150	
Crafton Heights Pipe Line Company	Redlands	390	
Crafton Mesa Mutual Water Company	Redlands	225	
Crafton Water Company	Redlands	1,400	
Crawford Canyon Mutual Water Company	Fontana		35
Cucamonga Water Company	Cucamonga	4,000	600
Cuttle, R. F., Inc.	San Bernardino	84	21
Daley Canyon Mutual Water Company	San Bernardino		30
Del Rosa Mutual Water Company	Del Rosa	256	
Devore Mutual Water Company	San Bernardino		109
Dillson Mutual Water Company	Del Rosa Heights		19
East Barton Water Company	Redlands	100	
East Colton Avenue Water Company	Mentone	130	
East Colton Heights Mutual Water Company	Colton	22	28
East Lugonia Mutual Water Company	Redlands	120	
East Pioneer Mutual Well Company	Redlands	155	
East Redlands Water Company	Redlands	440	
Eastwood Acres Community Water Company	San Bernardino	51	
Etiwanda Domestic Water Association	Etiwanda		165
Etiwanda Water Company	Etiwanda	1,600	
Eucalyptus Street Water Company	Highland	40	20
Euclid Water Company of Upland	Upland		
Fairview Water Company	Redlands	90	
Fallsvale Service Company	Fallsvale		350
Fawnskin Mutual Water Company	Fawnskin		721
Fifth Street Mutual Water Company	Ontario	175	
Fontana Union Water Company	Fontana	12,500	
Foothill Irrigation Company	Alta Loma	600	26
Gaylord Mutual Water Company	Ontario	120	
Gladysta Well and Water Company	Redlands	100	
Grand Avenue Pump Company	Ontario	84	
Grant Company Well	Redlands	100	
Greenspot Mutual Water Company	Greenspot	2,000	
Greenspot Mutual Well Company	Mentone	75	
Haws McKinley Well Company	Highland	90	
Hedges Well, Inc.	Alta Loma	250	
Hellman Water Company	Alta Loma	250	
Hermosa Water Company	Alta Loma	480	1
Highland Avenue Water Company	Fontana	25	40
Highland Haven Mutual Water Company	Fontana		2
Highland Well Company	Highland	100	
Hillside Wells Company	Alta Loma	100	
Holden Mutual Water Company	San Bernardino		42
Home Mutual Water Company	Ontario	240	
Hope Springs Eternal Well, Inc.	Pomona	70	
Inter-City Mutual Water Company	San Bernardino	80	107
Ioamosa Water Company	Alta Loma	580	35
Jewel Water Company	Redlands	130	
Joya Mutual Water Company	Upland	120	1
Judson Mutual Water Company	Redlands	150	
Jumal Water Company	Colton	130	
Kansas Street Water Company	Redlands	75	
King Street Mutual Well Company	Redlands	100	
Ladera Mutual Improvement Company	Loma Linda		123
Lakeside Well Company	Redlands	35	
Lankershim Street Mutual Well Company	Highland	25	118
Las Palmas Water Company	Redlands	20	20
San Bernardino County—Continued			
Mutual Water Companies—Continued			
Lemon Heights Water Company	Upland	300	
Limited Mutual Water Company	Ontario	320	
Linda Vista Water Company	Colton	400	
Loma Linda Home Tract Water Company	San Bernardino	4	75
Loma Linda Mutual Service Company	Loma Linda		180
Longacres Mutual Water Company	Fontana	50	7
Lower Yucaipa Water Company	Redlands	250	
Lugonia Park Water Company	Redlands	100	
Lugonia Water Company	Redlands	1,100	
Lugo Water Company	Redlands	130	
Lytle Creek Water and Improvement Company	Rialto	3,200	
Marabrae Mutual Water Company	Highland		35
Marygold Mutual Water Company	Bloomington	450	225
Mascart Water Company	Redlands	105	
Meeks and Daley Water Company	Colton	200	
Mentone Acres Mutual Well Company	Mentone	240	
Mentone Groves Company	Mentone	122	
Merryfield Water Company	Colton	170	
Mesa Linda Water Company	Alta Loma		60
Mill Creek Mutual Service Company	Mentone		54
Monte Vista Irrigation Company	Ontario	900	
Monte Vista Water Company	Pomona	300	
Moonridge Mutual Water Company	Big Bear Village	30	200
Mountain View Mutual Water Company	Ontario	210	5
Mountain View Park Mutual Water Company	Chino		20
Mountain View Water Company	Upland	850	1
Mount Harrison Mutual Water Company	East Highland	110	
Mount Vernon Water Company	San Bernardino	320	
MuscoyMutualWater Company No. 1	San Bernardino	1,100	1,000
Mutual Well Company	Highland	130	
Myrtle Mutual Water Company	San Bernardino		19
Nickerson Water Company No. 1	Redlands	60	
North Brae Water Company	Redlands	145	
North Fork Water Company	Highland	3,200	
North Shore Mutual Water Company	Fawnskin		29
North Side Water Company	Redlands	110	
Noyes Water Company	Ontario	235	4
Oakglen Domestic Water Company	Oakglen		38
Old Settlers Water Company	Cucamonga	140	
Olive Tree Lane Mutual Water Company	Highland		27
Ontario Water Company	Upland	250	
Orange Park Water Company	Ontario	77	1
Peach Park Water Company	Ontario	135	16
Penn Well Company	Redlands	116	
PepperCurve Mutual Water Company	Highland	45	20
Perris Hill Mutual Water Company	San Bernardino	90	2
Pharoah and Powell Water Company	Redlands	80	
Pioneer Mutual Water Company	Redlands	90	
Pomona Home Acres Mutual Water Company	Pomona	100	
Pomona Valley Water Company	Chino	110	199
Ramona Avenue Irrigation Company	Pomona	105	
Rancheria Water Company	San Bernardino	310	
Raught Mutual Well Company	Redlands	145	
Redlands Heights Water Company	Redlands	1,000	
Redlands Water Company	Redlands	1,300	
Rex Mutual Water Company	Alta Loma	125	1
Rialto Mutual Land and Water Company	Rialto	500	
Rochester Water Company	Cucamonga		23
Rocky Comfort Mutual Water Company	Redlands	50	23
Rosedale Water Company	Colton	83	
San Antonio Canyon Mutual Service Company	Upland		30
San Antonio Water Company	Upland	4,000	140
San Bernardino Avenue Water Company	Redlands	110	
Sapphire Mutual Water Company	Alta Loma		12
Schowalter Mutual Water Company	Alta Loma	100	11
Section 30 Mutual Water Company	Yucaipa	640	35
Seeley Well Company	Highland	80	

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
San Bernardino County—Continued			
Mutual Water Companies—Continued			
Slover Mutual Water Company	Rialto		19
Smith Tract Water Company	Redlands	90	
South Mesa Water Company	Calimesa	2,000	725
South Mountain Water Company	Redlands	500	
Southside Mutual Water Company	Ontario	210	
Stowe Water Company	Redlands	105	
Strawberry Lodge Mutual Water Company	San Bernardino		93
Sunset Water Company of Cucamonga	Cucamonga	185	
Tennessee Water Company	Redlands	145	
Terrace Water Company	Colton	150	275
Tioga Mutual Water Company	Upland	300	130
Treasure Island Mutual Water Company	Pine Knot		12
Tri-City Mutual Water Company	San Bernardino		40
Trible Falls Water Company	Yucaipa		
Upland Foothill Water Company	Upland	300	
Upland Water Company	Upland	300	
Valencia Drive Mutual Water Company	San Bernardino	20	
Valley Farms Mutual Water Company	San Bernardino	75	171
Valley View Park Mutual Water Company	Crestline		148
Victoria Farms Mutual Water Company	San Bernardino	100	105
Vista Grande Mutual Water Company	Colton		12
Walnut Street Pumping Plant	Chino	50	
Webster Mutual Water Company	San Bernardino		18
West End Consolidated Water Company	Upland	1,700	
Western Heights Water Company	Redlands	1,350	625
West Fourth Street Water Company	Ontario	210	
West Highlands Water Company	Patton	800	
West Highland Well Company	Del Rosa	150	
West Ontario Mutual Water Company	Ontario	160	
West Redlands Water Company	Redlands	800	
West Twin Creek Water Company	San Bernardino	290	
Williams Well Corporation, Ltd.	Redlands	120	
Woehr Mutual Water Company	Redlands	75	
Wrach Water Company	Chino	62	
Yucaipa Little Farms	Yucaipa	90	
Yucaipa Valley Mutual Water Company	Yucaipa	4	2
Yucaipa Water Company No. 1	Yucaipa	1,000	1,600
County Water Districts			
Bloomington County Water District	Bloomington		160
Crest Forest County Water District	Crestline		2
Monte Vista County Water District	Ontario		
County Waterworks Districts			
San Bernardino County Waterworks District No. 8	Chino		109
Municipal Water Districts			
Chino Basin Municipal Water District	Ontario, etc.	(Sells at sale)	whole-
San Bernardino Municipal Water District	San Bernardino Redlands, etc.	(Sells at sale)	whole-
Metropolitan Water Districts			
Metropolitan Water District of Southern California		(Sells at sale)	whole-
San Diego County			
Municipal Waterworks			
Escondido	Escondido		2,012
Oceanside	Oceanside		3,100
San Diego	San Diego		76,662

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
San Diego County—Continued			
Commercial Water Companies			
California Water and Telephone Company	Chula Vista Coronado National City and 8 others	3,100	12,016
Del Mar Utilities	Del Mar		506
Descanso Park Water Company	Descanso		60
Felicita Water Service	Escondido		12
Jesmond Dene Water System	Escondido		24
Moro Water Company	Fallbrook	26	4
Rock Springs Utility District	Escondido		2
Valley Center Water Company	Valley Center		4
Whispering Pines Water Company	Julian		96
Mutual Water Companies			
Bailey Mutual Water Company	Escondido		21
Bennett Mutual Water Company	Escondido	700	11
Bernita Mutual Water Company	El Cajon	23	10
Campo Water System	Campo	20	75
Canyon Ranch Mutual Water Company	Fallbrook	45	2
Carlsbad Mutual Water Company	Carlsbad	2,000	1,490
Chase Heirs Mutual Water Company	El Cajon	12	10
Del Dios Mutual Water Company	Escondido		150
Do-It Mutual Water Company	Bonsall	110	6
East San Pasqual Water Company	Escondido	237	
Escondido Mutual Water Company	Escondido	7,806	727
Green Mutual Water Company of San Diego	Escondido	300	75
Harbison Canyon Mutual Water Company	El Cajon		225
Harmony Grove Spiritualist Association	Escondido		26
High Valley Mutual Water Company	Poway	184	6
Julian Mutual Water Company	Julian		250
Lake Henshaw Resort Water System	Santa Ysabel		29
Lake Morena's Oak Shores Mutual Water Company, Inc.	Campo		75
Lake Morena Views Mutual Water Company	Lake Morena Village		34
Lakeside Farms Mutual Water Company	Lakeside	700	110
La Mesa Mutual Water Company	La Mesa	3	
Long View Mutual Water Company	Escondido	30	11
Los Tulas Mutual Water Company	Warner Hot Springs		18
Monserate Water Company	Fallbrook	89	7
Pala Indian Reservation	Pala	600	72
Palomar Mountain Mutual Water Company	Escondido		100
Pauma Valley Water Company	Pala	460	37
Pine Hills Mutual Water Company	Julian		51
Pine Valley Mutual Water Company	Pine Valley		155
Pratt Mutual Water Company	Fallbrook	4	1
Riverview Farms Mutual Water Company	San Diego	1,000	465
San Luis Rey Heights Mutual Water Company	Bonsall	600	35
San Marcos Water Developers	San Marcos		40
Santa Margarita Mutual Water Company			
S.E.R.J. Mutual Water Company	El Cajon	30	6
Tavern Water System	Alpine		6
Terramar Water Company	Carlsbad	250	25
Vista Manor Mutual Water Company	Vista		6
Willows Water System	Alpine		17
Willowside Terrace Water Association	El Cajon		18
Winterwarm Mutual Water Company	Fallbrook	240	40
County Water Districts			
San Marcos County Water District	San Marcos		

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
San Diego County—Continued			
Irrigation Districts			
Lakeside Irrigation District	Lakeside		500
La Mesa, Lemon Grove and Spring Valley Irrigation District	La Mesa	12,008	18,000
Ramona Irrigation District	Ramona	14	359
San Dieguito Irrigation District	Encinitas	1,670	2,023
Santa Fe Irrigation District	Encinitas	2,470	923
San Ysidro Irrigation District	San Ysidro	400	823
South Bay Irrigation District		3,782	
Vista Irrigation District	Vista	9,000	
Water Districts			
Belfort Village Water District			
Bonsall Heights Water District	Bonsall		
Las Posas Water District			
Moosa Water District	Bonsall		
Orchard Water District			
Public Utility Districts			
Fallbrook Public Utility District	Fallbrook	8,192	1,250
Municipal Water Districts			
Bueno Colorado Municipal Water District	Vista, etc.		
Carlsbad Municipal Water District	Carlsbad		
Poway Municipal Water District	Poway		
Rainbow Municipal Water District	Rainbow, etc.		
Ramona Municipal Water District	Ramona		
Rincon del Diablo Municipal Water District	Escondido		
Valley Center Municipal Water District	Valley Center		
County Water Authorities			
San Diego County Water Authority		(Sells at sale)	whole-
Metropolitan Water Districts			
Metropolitan Water District of Southern California		(Sells at sale)	whole-
Ventura County			
Municipal Waterworks			
Fillmore	Fillmore		1,093
Oxnard	Oxnard		4,165
Port Hueneme	Port Hueneme		750
Ventura	Ventura		6,124
Commercial Water Companies			
Farmers Irrigation Company	Santa Paula		
Gardens Water Corporation	Oak View		424
Santa Clara Water and Irrigating Company	Saticoy	600	
Santa Paula Water Works, Ltd.	Santa Paula	760	3,367
Saticoy Water Company	Saticoy-Montalvo		906
Southern California Water Company	Ojai		1,091
Warring Brothers Domestic Service	Piru		256
Warring Brothers Irrigating Service	Piru	400	
Yerba Buena Water Company	Solromar		15
Mutual Water Companies			
Agee's Farms Mutual Water Company	Oxnard	40	
Aliso Mutual Water Company	Saticoy	110	6
Alta Mutual Water Company	Saticoy	1,800	59
Arnaz Mutual Water Company	Oak View	33	49
Bardsdale Water Supply	Fillmore		35
Berylwood Heights Mutual Water Company	Somis	700	
Brownstone Mutual Water Company	Fillmore	125	2
Casitas Mutual Water Company	Casitas	15	80
Cienega Water Company	Fillmore	290	10
Citrus Mutual Water Company	Santa Paula	250	
Cloverdale Mutual Water Company	El Rio	101	90
Community Mutual Water Company	Santa Paula	432	14
Conejo Mutual Water Company	Camarillo	212	16
Cozy Dell Eucalyptus Company	Ojai		5
Crestview Mutual Water Company	Camarillo	48	9

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Ventura County—Continued			
Mutual Water Companies—Continued			
Cyprus Mutual Water Company	Port Hueneme		62
Del Norte Water Company	Saticoy	1,200	24
Dempsey Road Mutual Water Company	Oxnard		287
Elmobo Mutual Water Company	Fillmore	150	3
El Rio Mutual Water Company	El Rio		105
Epworth Mutual Water Company	Moorpark	70	5
Fillmore Irrigation Company	Fillmore	875	100
Garden Acres Mutual Water Company	Camarillo		90
Hardscrabble Water Company	Santa Paula	252	
Hollywood Beach Mutual Water Company	Oxnard		158
Hollywood by the Sea Mutual Water Corporation	Oxnard		95
Kadota Mutual Water Company	Santa Susana	319	138
Lake Sherwood Mutual Water Company	Camarillo		80
La Placentia Mutual Water Company	Simi	60	
Las Posas Water Company	Somis		167
Los Encinos Mutual Water Company	Ojai		15
Lucky Seven Mutual Water Company	Oak View	6	7
Mesita Mutual Water Company	Oak View	40	14
Mira Monte Mutual Water Company	Ojai	250	160
Montalvo Mutual Water Company	Montalvo	900	
Montgomery Mutual Water Company	Simi	400	17
Moorpark Home Acres Mutual Water Company	Moorpark	180	62
Moorpark Mutual Water Company	Moorpark	600	
Mound Mutual Water Company	Ventura	853	264
Mutual Water Company of Vineyard Avenue Estates	Oxnard		85
North Oxnard Mutual Water Company	Oxnard	3	3
Ocean View Mutual Water Company			
O'Conner-Camarillo Ranches Mutual Water Company	Camarillo	435	
Olive Mutual Water Company	Ojai	50	
Oxnard Mutual Water Company	Oxnard	2,800	
Pleasant Valley Mutual Water Company	Camarillo		347
Ranchitos Mutual Water Company	Ojai	40	90
Rancho Santa Ana Vista Water Company	Oak View		6
Rissman Mutual Water Company	Piru	83	10
San Cayetano Mutual Water Company	Santa Paula	350	14
San Miguel Mutual Water Company	Ventura	210	
Santa Clara Mutual Water Company	Saticoy	200	6
Santa Rosa Mutual Water Company	Camarillo	557	20
Senior Canyon Mutual Water Company	Ojai	115	100
Sherwin Acres Mutual Water Company	Ventura	27	44
Siete Robles Mutual Water Company	Ojai	5	65
Silver Strand Mutual Water Company	Oxnard		225
Simi Hills Development Association	Canoga Park		125
Simi Mutual Water Company	Simi	90	67
Simi Valley Mutual Water Company	Simi		53
Sinaloa Mutual Water Company	Simi	500	20
Sisar Mutual Water Company	Ojai		32
Skyline Mutual Water Company	Ojai	100	5
Southside Improvement Company	Fillmore	1,478	16
South Slope Mutual Water Company	Simi	257	
Stork Mutual Water Company	Santa Paula	15	1
Susana Water Company	Ventura		255
Tapo Mutual Water Company	Santa Susana	1,113	83
Teal Club Mutual Water Company	Oxnard	4	8
Thermal Belt Water Company	Santa Paula	1,380	50
Thermic Mutual Water Company	Moorpark	500	14
Tico Mutual Water Company	Ojai	52	9
Timber Canyon Mutual Water Company	Santa Paula	60	3
Turner Ditch Company	Santa Paula	259	
Ventura River Mutual Water Company	Ojai		70
Vineyard Avenue Acres Mutual Water Company	Oxnard	122	116
Vineyard Mutual Water Company	Oxnard	200	
Zone Mutual Water Company No. 1 and No. 2	Somis	3,351	

WATER SERVICE AGENCIES, SOUTH COASTAL AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Ventura County—Continued			
County Water Districts			
Meiners Oaks County Water District	Meiners Oaks	200	574
County Waterworks Districts			
County Waterworks District No. 1, Moorpark	Moorpark		375
County Waterworks District No. 3, Simi	Simi	60	100
County Waterworks District No. 4, Casitas Springs	Casitas Springs		90
County Waterworks District No. 5, Camarillo	Camarillo		420
County Waterworks District No. 6, Thousand Oaks	Thousand Oaks		330
Ventura County—Continued			
County Waterworks Districts—Continued			
County Waterworks District No. 7, Live Oak Acres	Live Oak Acres		85
Water Conservation Districts			
Simi Valley Water Conservation District	Simi Valley	10,000	
United Water Conservation District	Santa Paula	68,000	13,500
Special Water Service Districts			
Montalvo Municipal Improvement District	Montalvo		
Ventura County Flood Control District			

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Alameda County			
Irrigation Districts			
Byron-Bethany Irrigation District	Byron	(See Contra Costa County)	
Amador County			
Municipal Waterworks			
Plymouth	Plymouth		222
Commercial Water Companies			
Arroyo Ditch Company	Plymouth	100	16
Jackson Gate Water Works	Jackson Gate		45
Jackson Water Works	Jackson		727
Outingdale Water Company	Placerville		32
Pacific Gas and Electric Company	Amador City, Ione, Sutter Creek		844
River Pines Water Service	River Pines	5	151
Mutual Water Companies			
Volcano Water System	Volcano		30
Butte County			
Municipal Waterworks			
Biggs	Biggs		297
Chico Municipal Airport Water Supply	Chico		45
Gridley	Gridley		1,170
Commercial Water Companies			
California Water Service Company	Chico, Oroville		9,181
Diamond Match Company, The	Sterling City		367
Mulberry Water Works	Chico		112
Pacific Gas and Electric Company	Nelson	17,586	
Sutter Butte Canal Company	Gridley-Biggs	16,997	
Mutual Water Companies			
Ayers Mutual Water Company	Gridley	5	21
Biggs Ditch Company	Biggs	450	
Dayton Mutual Water Company	Chico	1,868	
De Sabla Water Supply	Paradise		22
Durham Mutual Water Company, Ltd.	Durham	5,800	
Las Plumas Water Supply	Oroville		19
Water Users Association Gridley Colony, Ditch No. 1	Gridley	1,200	
Irrigation Districts			
Durham Irrigation District	Durham		166
Oroville-Wyandotte Irrigation District	Oroville	4,450	1,015
Paradise Irrigation District	Paradise	450	2,814
Richvale Irrigation District	Richvale	13,475	
Table Mountain Irrigation District	Oroville	450	
Thermalito Irrigation District	Oroville	1,670	1,000
Reclamation Districts			
Reclamation District 833	Gridley	10,000	
Water Districts			
Biggs West Gridley Water District	Biggs	11,837	
Butte Water Company	Gridley	17,000	
Calaveras County			
Commercial Water Companies			
Pacific Gas and Electric Company	Altaville, Angels Camp		534
Mutual Water Companies			
Angels Water Users Associations	Angels Camp	160	
West Point Ditch Company	West Point	20	40
County Water Districts			
Calaveras County Water District No. 1	Angels Camp		45
Water Districts			
Rock Creek Water District	Farmington	700	4
Calaveras County—Continued			
Public Utility Districts			
Calaveras Public Utility District	Mokelumne Hill, San Andreas		600
Union Public Utility District	Murphys	401	530
Valley Springs Public Utility District	Valley Springs		120
Colusa County			
Municipal Waterworks			
Colusa	Colusa		974
Williams	Williams		420
Mutual Water Companies			
Beduhn Water Supply	Colusa		8
Colusa Irrigation Company	Colusa	1,200	25
Roberts Ditch Irrigation Company	Colusa	1,400	
Swinford Tract Irrigation Company	Colusa	136	
Irrigation Districts			
Compton-Delevan Irrigation District	Maxwell	3,022	
Glenn-Colusa Irrigation District	Delevan	73,687	
Maxwell Irrigation District	Maxwell	1,730	
Princeton-Codora-Glenn Irrigation District	Princeton	(See Glenn County)	
Provident Irrigation District	Princeton	(See Glenn County)	
County Waterworks Districts			
Princeton County Waterworks District	Princeton		85
Reclamation Districts			
Reclamation District 108	Grimes	12,661	
Reclamation District 1004	Colusa	11,460	
Water Districts			
Compton Water District	Maxwell	3,500	
Public Utility Districts			
Arbuckle Public Utility District	Arbuckle		285
Maxwell Public Utility District	Maxwell		238
Contra Costa County			
Municipal Waterworks			
Antioch	Antioch		3,490
Commercial Water Companies			
Pleasantimes Water System	Bethel Island		97
Mutual Water Companies			
Bethel Island Mutual Water Company	Bethel Island		50
Farrar Park Property Owners Water Company	Oakley		50
Loreto Megna Water Company	Antioch	30	50
River View Water Association	Oakley		9
Sandmound Mutual Water Company	Oakley		72
County Water Districts			
Contra Costa County Water District	Pittsburg	(See Table 2)	
Irrigation Districts			
Byron-Bethany Irrigation District	Byron	9,030	
East Contra Costa Irrigation District	Brentwood	16,125	
County Waterworks Districts			
Contra Costa County Waterworks District No. 1	Brentwood		325
Reclamation Districts			
Reclamation District 830	Oakley	3,500	
Reclamation District 1619	Brentwood	2,200	750
Reclamation District 2024	Brentwood	2,369	
Reclamation District 2059		2,000	
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at wholesale)	

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
El Dorado County			
Municipal Waterworks			
Placerville	Placerville		1,374
Commercial Water Companies			
Farmers Ditch Company	Coloma	90	
Georgetown Divide Water Company, Ltd.	Georgetown		47
Juckes, J. W., Water and Ditch System	Pleasant Valley		1
Randall Ditch Company	Folsom		
Mutual Water Companies			
Caldor Lumber Company	Diamond Spring		34
Mosquito District Mutual Water Company	Placerville	400	4
West Spring Mutual Water Company	Pollock Pines		5
Irrigation Districts			
El Dorado Irrigation District	Placerville	5,700	585
Public Utility Districts			
Georgetown Divide Public Utility District	Georgetown	1,600	102
Pollock Pines-Fresh Pond Public Utility District	Pollock Pines		112
United States Bureau of Reclamation Projects			
Central Valley Project-Sly Park Unit		(Sells at wholesale)	
Fresno County			
Municipal Waterworks			
Clovis	Clovis		850
Coalinga	Coalinga		1,810
Firebaugh	Firebaugh		293
Fowler	Fowler		527
Fresno	Fresno		39,177
Kerman	Kerman		400
Kingsburg	Kingsburg		872
Mendota	Mendota		250
Orange Cove	Orange Cove		547
Parlier	Parlier		368
Reedley	Reedley		1,490
San Joaquin	San Joaquin		122
Sanger	Sanger		1,789
Commercial Water Companies			
Bakman Homesites Water Utility	Fresno		140
Biola Water Company	Biola		143
Bowen Land Company Water System	Fresno		72
Calwa City Water Company	Calwa		871
Caruthers Water Company	Caruthers		161
Cedar Heights Water System	Fresno		35
Del Rey Water Works	Del Rey		174
East Mendota Water Company	Mendota		90
Fresno Suburban Water Service Company	Fresno		62
Gardenview Water System	Fresno		140
Highway City Water System	Highway City		349
Huron Utility Company	Huron		108
Kavanagh Vista Water Company	Fresno		61
Laton Water Company	Laton		182
Mendocino Heights Water Company	Kingsburg	20	2
Mouren Water Service	Huron		73
Northeast Gardens Water System	Fresno	30	61
Pacific Gas and Electric Company	Selma		1,773
Pinedale Water Company	Pinedale		504
Spangler Water System	Fresno		31
Walker Water Company	Parlier		30
Whitener Heights Water Company	Parlier		37
Yosemite Garden Water Company	Pinedale		60
Mutual Water Companies			
California Cotton Compress and Warehouse	Pinedale		57
Columbia Canal Company	Firebaugh	(See Madera County)	

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Fresno County—Continued			
Mutual Water Companies—Continued			
Crescent Canal Company	Lanare	12,500	
Dennis-Byrd Ditches	Reedley	1,200	
Eagle Field Water Association	So. Dos Palos	(See Merced County)	
Firebaugh Canal Company	Firebaugh	23,675	4
Hanke Ditch Association	Sanger	1,390	14
Kilpatrick Water Supply	Orange Cove		8
Kings River Bottoms Water Users Association	Sanger	9,000	
Kings River Mutual Water Company	Reedley	130	2
Las Deltas Mutual Water Company	Firebaugh		31
Liberty Canal Company	Burrel	4,000	
Liberty Mill Race Company	Riverdale	21,120	
Music Meadows Mutual Water Company	Fresno		12
New Auberry Water Association	New Auberry		37
North Elderwood Water Company	Fresno	70	
Ora Loma Water Association	Dos Palos	431	
Orange Vale Water Company	Reedley	96	
Reed Ditch Company	Burrel	6,000	
Round Mountain Water Association	Clovis	135	
South Reedley Mutual Water Company	Reedley	10	20
Widren Water Users' Association	Firebaugh	850	
Irrigation Districts			
Alta Irrigation District	Reedley	(See Tulare County)	
Central California Irrigation District		(See Merced County)	
Consolidated Irrigation District	Selma	140,000	
Fresno Irrigation District	Fresno	169,800	
Hills Valley Irrigation District	Orange Cove	0	
James Irrigation District	San Joaquin	16,917	
Laguna Irrigation District	Laton	30,000	
Mendota Irrigation District	Tranquillity	(Inactive)	
Orange Cove Irrigation District	Orange Cove	15,532	
Riverdale Irrigation District	Riverdale	13,380	
Stinson Irrigation District	Burrel	6,000	
Tranquillity Irrigation District	Tranquillity	8,112	175
County Waterworks Districts			
Fresno County Waterworks District No. 1	Fresno		570
Fresno County Waterworks District No. 2	Fresno		254
Fresno County Waterworks District No 3	Fresno		170
Fresno County Waterworks District No. 4	Fresno		1,400
Fresno County Waterworks District No. 5	Fresno		14
Fresno County Waterworks District No. 6	Fresno		32
Fresno County Waterworks District No. 7	Fresno		80
Fresno County Waterworks District No. 8	Fresno		100
Reclamation Districts			
Reclamation District 779	Fresno	25,309	
Reclamation District No. 1003	Laton	1,500	43
Water Districts			
Borland Water District	Mendota	3,499	
Farmers Water District	Mendota	2,300	
International Water District	Clovis	160	
Oro Loma Water District	South Dos Palos	622	
Panoche Water District	Dos Palos	41,000	
Westlands Water District	Helm		
Water Conservation Districts			
Kings River Water Conservation District	Fresno	900,000	
Community Services Districts			
Wahtoke Community Services District	Orange Cove	4,468	

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Fresno County—Continued			
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at wholesale)	
Glenn County			
Municipal Waterworks			
Orland	Orland		708
Commercial Water Companies			
California Water Service Company	Willows		1,339
Pacific Gas and Electric Company	Butte City	(See Butte County)	
Sacramento River Farms, Ltd.	Hamilton City		150
Mutual Water Companies			
Butte City Water Works	Butte City		35
Davis Water Service	Willows		20
Loam Ridge Mutual Water Company	Orland	1,000	
Orland Unit Water Users' Association	Orland	22,430	
Willow Creek Mutual Water Company	Willows	750	
Irrigation Districts			
Glenn-Colusa Irrigation District	Delevan	(See Colusa County)	
Jacinto Irrigation District	Willows	9,095	
Princeton-Codora-Glenn Irrigation District	Willows	6,848	
Provident Irrigation District	Glenn	10,579	
Reclamation Districts			
Reclamation District 1004		(See Colusa County)	
Kern County			
Municipal Waterworks			
Delano	Delano		2,100
Maricopa	Maricopa		
Tehachapi	Tehachapi		450
Commercial Water Companies			
Arden Water Company	Kernville		43
Arvin Water Company	Arvin		1,055
Buena Vista Canal, Inc.	Bakersfield	17,300	
California Water Service Company	Bakersfield		23,905
Calimar Water Company	Bakersfield		200
Central Canal Company (Calloway)	Bakersfield	63,115	
Commercial Land Company	Tupman		62
East Side Canal Company	Bakersfield	6,293	
Farmers Canal Company	Bakersfield	10,210	
Garden Acres Water Company	Bakersfield		350
Hicks, E. B., Water Company	Bakersfield		100
Kern Island Canal Company	Bakersfield	53,720	
Kern River Canal and Irrigating Company	Bakersfield	9,190	
Kernville Domestic Water System	Kernville		36
Lebec Water Works	Lebec		73
Lost Hills Water Company	Lost Hills		106
McKittrick Water Company	McKittrick		62
Pacific Water Company	Bakersfield Lamont Wasco	170	2,064
Sage Brothers Water Service	South Shafter	3	94
Stine Canal, Inc.	Bakersfield	21,900	
Western Water Company	Fellows Ford City Maricopa Taft		5,406
Mutual Water Companies			
Airport Mutual Water Company	Bakersfield	40	68
Alamont Mutual Water Company	Lamont	19	96
Alta Sierra Mutual Water Company	Bakersfield		92
Anderson Canal, Inc.	Bakersfield	2,420	
Baldwin Diary	Bakersfield	2,300	4
Barnes Water Supply	Bakersfield		24
Bear Mountain Orange Company	Arvin	560	7
Broce Mutual Water Company	McFarland	121	
Casa Loma Water Company	Bakersfield	160	190

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Kern County—Continued			
Mutual Water Companies—Continued			
Castro Ditch Company	Bakersfield	250	
Chanslor-Canfield Midway Oil Company	Bakersfield		139
Comanche Point Water Company	Arvin	240	7
DeWitte's Auto Court	Shafter		85
DiGiorgio Fruit Corporation	Bakersfield	10,000	3
Dos Pinos Mutual Water Company	Lamont		66
East Buttonwillow Mutual Water Company	Buttonwillow		8
Edison Mutual Water Company	Bakersfield		61
Edmondson Acres Mutual Water Company	Arvin	15	28
First Edison Well Company	Bakersfield	412	
Foothill Citrus Farms Company	Arvin	225	
Fox Trailer Court	Bakersfield		30
Garfield Community Water Supply Company	Bodfish		16
Green Acres Mutual Water Users	Delano	74	12
James and Dixon Canal Company, Inc.	Bakersfield	2,240	
Jellison, F. D.	Bakersfield	100	
Johnson Canal Company	Bakersfield	1,200	
Joyce Canal Company, Inc.	Bakersfield	1,920	
Kern Mutual Water Company	Buttonwillow		275
Lamont Mutual Water Company	Lamont	40	20
Lerdo Canal Company, Inc.	Lerdo	20,835	
Lerdo Mutual Water Company No. 9	Lerdo	300	
Loma Park Water Company	Bakersfield	140	60
Los Patos Land and Water Company	Bakersfield	60	1
McFarland Mutual Water Company	McFarland		685
Mettler Mutual Water Company	Mettler Station		12
Mexican Colony Water Association	Shafter		84
Miracle Hot Springs Resort	Bakersfield		20
Montal Mutual Water Company	Lamont	20	112
Monte Vista Mutual Water Company	Bakersfield		15
Nightingale, C. E.	Shafter	1	6
Norris Terrace Mutual Water Company	Bakersfield		44
Oildale Mutual Water Company	Oildale		4,000
Old South Fork Company	Bakersfield	1,700	
Pioneer Canal Company	Bakersfield	12,190	
Plunket Canal, Inc.	Bakersfield	1,420	
Richards, Pauly and Tupman	Arvin	320	6
Rag Gulch Mutual Water Company	Delano	732	
Riverkern Mutual Water Company	Kernville		8
San Marino Mutual Water Company			13
Second Edison Well Company	Bakersfield	300	
Shady Acres Auto Camp	Bakersfield		23
Stockdale Mutual Water Company	Bakersfield		55
Sunny Street Mutual Water Company	Shafter		15
Vaughn Water Company, Inc.	Bakersfield		110
Wildwood Farm	Bakersfield	500	1
Williams, Peter M.	Bakersfield	30	90
Willowood Mutual Water Company	Bakersfield	18	
Wilson Ditch	Bakersfield	250	
Wise, H. H.	Bakersfield	10	8
Irrigation Districts			
Delano-Earlimart Irrigation District	Earlimart	(See Tulare County)	
Shafter-Wasco Irrigation District	Shafter	30,407	
Water Storage Districts			
Arvin-Edison Water Storage District	Arvin	95,011	
Buena Vista Water Storage District	Bakersfield	40,291	
North Kern Water Storage District	Famoso	50,000	
Public Utility Districts			
Frazier Park Public Utility District	Bakersfield		391
Highland Park Public Utility District	Bakersfield		903
Lamont Public Utility District	Lamont		470
Plainview Public Utility District	Bakersfield		150
Wasco Public Utility District	Wasco		1,400
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at wholesale)	

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Kern County—Continued			
Municipal Utility Districts			
Southern San Joaquin Municipal Utility District	Delano	53,000	
Kings County			
Municipal Waterworks			
Corcoran	Corcoran		920
Lemoore	Lemoore		875
Commercial Water Companies			
California Water Service Company	Hanford		4,020
Kettleman City Water Company	Kettleman City		95
Lone Oaks Canal Company	Hanford	5,000	
Pacific Gas and Electric Company	Avenal		1,309
Mutual Water Companies			
Bayou Vista Ditch Company	Corcoran	8,500	
Burke Ditch Company	Hanford	640	
Gates-Jones Mutual Water Company	Corcoran		
Hamblin Mutual Water Company	Hanford	10	40
Hardwick Water Works	Hanford		35
John Heinlen Mutual Water Company	Lemoore		
Lakeside Ditch Company	Hanford	9,610	
Last Chance Water Ditch Company	Hanford	38,000	
Lemoore Canal and Irrigation Company	Lemoore	50,000	
Liberty Farms Mutual Water Company	Corcoran	16,410	
Melga Canal Company	Corcoran	30,000	
Peoples Ditch Company	Hanford	65,872	
Riverside Ditch Company	Hanford	3,615	
Settlers Ditch Company	Hanford	2,600	
Tulare Lake Canal Company	Stratford	37,000	
York Drop Ditch Company	Lemoore	2,700	30
Irrigation Districts			
Alta Irrigation District	Reedley	(See Tulare County)	
Consolidated Irrigation District	Selma	(See Fresno County)	
Corcoran Irrigation District	Corcoran	32,975	
Empire West Side Irrigation District	Hanford	6,400	
Island No. 3 Irrigation District	Traver		
Kings River Delta Irrigation District	Hanford	2,700	
Laguna Irrigation District	Laton	(See Fresno County)	
Lemoore Irrigation District	Lemoore	(Inactive)	
Lucerne Irrigation District	Hanford	(Inactive)	
Stratford Irrigation District	Hanford	9,846	
Reclamation Districts			
Reclamation District 739 (Lovelace)	Stratford	5,959	
Reclamation District 761 (Cohn Central Consolidated)	Stratford	18,000	
Reclamation District 780 (Homeland)	Alpaugh	24,290	
Reclamation District 2069 (Clark's Fork)	Lemoore	2,300	56
Water Districts			
Nunes Water District	Corcoran	18,900	
Water Storage Districts			
Tulare Lake Basin Water Storage District			
Special Water Service Districts			
Avenal Community Services District	Avenal		
Lake County			
Municipal Waterworks			
Lakeport	Lakeport		856
Commercial Water Companies			
Anderson Springs Water Company	Anderson Springs, Middletown		92
Lake County—Continued			
Commercial Water Companies—Continued			
Clear Lake Park Water Company	Austins, Clearlake Park, Pine Dell		468
Cobb Mountain Water Company	Cobb		1
Lucerne Water Company	Lucerne		177
Mutual Water Companies			
Clearlake Oaks Water Company	Clearlake Oaks		400
Crescent Bay Improvement Company	Lower Lake	2	28
Glenhaven Mutual Water Company	Glenhaven		54
Highlands Water Company	Clearlake Highlands		416
Jago's Resort Water Supply	Lower Lake	10	10
Lakewood Resort Water Supply	Kelseyville		14
Loch Lomond Mutual Water Company	Kelseyville		122
Manakee Mutual Water Company, Inc.	Clearlake Highlands		55
Nice Mutual Water Company	Nice		30
Sulphur Bank Mine	Clearlake Oaks		12
County Waterworks Districts			
Lower Lake County Waterworks District No. 1	Lower Lake		107
Kelseyville County Waterworks District No. 3	Kelseyville		140
Lassen County			
Commercial Water Companies			
Hunt, W. H., Estate Company	Adin	70	5
Northern Counties Utility Company	Westwood		1,087
Irrigation Districts			
Big Valley Irrigation District	Bieber Station	2,100	
Madera County			
Municipal Waterworks			
Chowchilla	Chowchilla		1,050
Madera	Madera		3,200
Commercial Water Companies			
Cunningham, Bessie L.	Central Camp		38
Raymond Water Works	Raymond		44
Mutual Water Companies			
Ashview Mutual Water Company	Chowchilla	8,000	
Bliss Ranch Company	Chowchilla	920	5
Bonita Mutual Water Company	Madera	9,202	
Columbia Canal Company	Firebaugh	16,560	
First Ventura-Madera Water Company	Madera	160	
Gravelly Ford Water Association, Inc.	Madera	2,500	
Heer Camp	Chowchilla	160	6
Justin Mutual Water Company	Chowchilla	4,510	
Kilcrease Camp Water Supply	Madera	320	1
Midvale Addition Water System	Madera		80
Redwood Acres Mutual Water Company	Madera		4
Sierra Linda Mutual Water Company	North Fork		4
Sierra Vista Mutual Water Company	Chowchilla	3,600	
Sugar Pine Properties Water Supply	Sugar Pine	10	40
Weatherly Mutual Water Company	North Fork		18
Irrigation Districts			
Madera Irrigation District	Madera	88,688	
Water Districts			
Chowchilla Water District	Chowchilla	62,574	
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at wholesale)	

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Mariposa County			
Mutual Water Companies			
Fish Camp Mutual Water Company	Mariposa		53
Wawona Mutual Water Company	Wawona		25
Public Utility Districts			
Mariposa Public Utility District	Mariposa		150
Merced County			
Municipal Waterworks			
Atwater	Atwater		910
Dos Palos	Dos Palos		520
Gustine	Gustine		610
Livingston	Livingston		440
Los Banos	Los Banos		1,300
Commercial Water Companies			
Crocker-Huffman Land and Water Company	Merced		4,723
East Side Canal and Irrigation Company	Stevinson	5,935	
Le Grand Water Company	Le Grand		85
Myrtle Acres Water Service	Winton		24
Snelling Water Works	Snelling		37
South Dos Palos Water Works	Dos Palos		80
Winton Water Works	Winton		125
Mutual Water Companies			
Castle Garden Homes, Inc.	Atwater		501
Eagle Field Water Association	South Dos Palos	6,038	
Hilmar Water Works	Hilmar		86
Occidental Canal Company	Gustine	50	
Planada Water Company	Planada		325
Red Top Camp Ranch	Merced	5,000	20
San Luis Canal Company	Los Banos	42,979	
Santa Nella Water Company	Gustine	73	
Sierra Vista Mutual Water Company	Chowchilla	(See Madera County)	
Irrigation Districts			
Central California Irrigation District	Los Banos	132,436	
El Nido Irrigation District	El Nido	7,295	
Merced Irrigation District	Merced	145,348	14
Turlock Irrigation District	Turlock	(See Stanislaus County)	
West Stanislaus Irrigation District	Westley	(See Stanislaus County)	
Water Districts			
Grass Lands Water District			
Mustang Water District	Gustine	281	
Panoche Water District	Dos Palos	(See Fresno County)	
Quinto Water District	Gustine	538	
Romero Water District	Volta	544	
San Luis Water District	Los Banos	13,152	83
Stevinson Water District	Stevinson	20,000	
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at wholesale)	
Modoc County			
Municipal Waterworks			
Alturas	Alturas		
Commercial Water Companies			
Hunt, W. H., Estate Company	Adin	(See Lassen County)	
Thomas and Bayne Ditch Company	Alturas	560	
Mutual Water Companies			
Willow Ranch Company	Willow Ranch		52
Irrigation Districts			
Big Valley Irrigation District	Bieber Station	(See Lassen County)	
Hot Springs Valley Irrigation District	Canby	4,000	
South Fork Irrigation District	Alturas	12,404	

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Napa County			
Mutual Water Companies			
Haus Water Supply	Pope Valley		5
Nevada County			
Municipal Waterworks			
Grass Valley	Grass Valley		1,800
Nevada City	Nevada City		900
Commercial Water Companies			
Graniteville Water Works	Graniteville		19
Mutual Water Companies			
Washington Water Supply	Washington	20	21
Irrigation Districts			
Nevada Irrigation District	Grass Valley	19,807	2,493
Public Utility Districts			
Donner Summit Public Utility District	Soda Springs		
Placer County			
Municipal Waterworks			
Lincoln	Lincoln		850
Roseville	Roseville		3,339
Commercial Water Companies			
Dutch Flat Water Works	Dutch Flat		92
Frey Water Company	Weimar		24
McGee Irrigation Company	Applegate	40	8
Pacific Gas and Electric Company	Auburn Colfax Loomis Newcastle Rocklin		2,304
Mutual Water Companies			
Morgan Tract Water Users Association	Auburn		20
Timber Hills Water Users	Weimar	20	10
Irrigation Districts			
Camp Far West Irrigation District	Sheridan	2,085	
Citrus Heights Irrigation District	Citrus Heights	(See Sacramento County)	
Nevada Irrigation District	Grass Valley	(See Nevada County)	
Water Districts			
Meadow Vista Water District	Applegate		125
Public Utility Districts			
Donner Summit Public Utility District	Soda Springs	(See Nevada County)	
Foresthill Public Utility District	Foresthill	300	
Community Services Districts			
San Juan Suburban Water District	Citrus Heights	(See Sacramento County)	
Plumas County			
Commercial Water Companies			
Bidwell Water Company	Greenville		379
Meadow Valley Guest Ranch	Meadow Valley	26	10
Portola Water Company, Inc.	Portola		680
Quincy Water Company	Quincy	207	477
Sorsoli Water Company	Crescent Mills		56
Sacramento County			
Municipal Waterworks			
Sacramento	Sacramento		39,794
Commercial Water Companies			
American River Water Service	Sacramento		70
Ben Ali Water Company	North Sacramento		4,350
Capitol Accommodations, Inc.	North Sacramento		1,050
Citizens Utilities Company of California	North Sacramento		4,932

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Sacramento County—Continued			
Commercial Water Companies—Continued			
Del Paso Water Company	Del Paso Manor		979
El Camino Water Company	North Sacramento		60
Elk Grove Water Works	Elk Grove		398
Freeport Water Company	Freeport		439
Fruitridge Vista Water Company	Sacramento		364
Hannum, Max, Water Service	Walnut Grove		88
Isleton Water Works	Isleton		298
K. P. Tract Water Company	Sacramento		11
Natomas Water Company	Folsom Natomas	6	500
Roland Water Company	Sacramento		16
Southern California Water Company	South Sacramento		3,286
Southland Water Company	Sacramento		30
Tallac Village Water Company	Sacramento		1,200
Mutual Water Companies			
Cosumnes Water and Irrigation Association	Sacramento	1,000	
Dunmovin Heights Mutual Water Company	Sacramento		22
Elkhorn Mutual Water Company	Sacramento	5,300	
Hidden River Vista Water Company	Carmichael		15
Natomas Central Mutual Water Company	Sacramento	7,799	
Natomas Riverside Mutual Water Company	Sacramento	20,174	
Noonans South Land Park Water Supply	Sacramento		25
Orangevale Water Company	Orangevale		650
Riverside Mutual Water Company	Sacramento	1,767	
South Land Park Terrace	Sacramento		35
Tokay Park Water Company, Inc.	Florin		10
County Water Districts			
Galt County Water District	Galt		400
Rio Linda County Water District	Rio Linda		260
Irrigation Districts			
Carmichael Irrigation District	Carmichael		2,027
Citrus Heights Irrigation District	Roseville	1,200	1,565
Elk Grove Irrigation District	Elk Grove	23,200	
Fair Oaks Irrigation District	Fair Oaks		1,535
Galt Irrigation District	Galt		
Reclamation Districts			
Reclamation District 3	Ryde	16,000	
Reclamation District 136	Walnut Grove	437	
Reclamation District 341	Rio Vista	10,348	
Reclamation District 364	Walnut Grove	1,369	
Reclamation District 407	Isleton	1,539	
Reclamation District 532	Isleton	1,969	
Reclamation District 551	Courtland	8,500	
Reclamation District 556	Walnut Grove	2,234	50
Reclamation District 563	Walnut Grove	4,584	
Reclamation District 744	Sacramento	1,500	24
Reclamation District 755	Courtland	384	12
Reclamation District 807	Walnut Grove	199	
Reclamation District 824	Sacramento	464	50
Reclamation District 1601	Rio Vista	3,617	
Reclamation District 2067	Rio Vista	7,049	
Water Districts			
Cosumnes River Water District	Michigan Bar	631	
Municipal Improvement Districts and County Maintenance Districts			
Arcade Oaks Terrace Maintenance District	Sacramento		18
Arden Park Vista Maintenance District	Sacramento		1,500
Land Park Water Maintenance District	Sacramento		220
Planehaven Water Maintenance District	Sacramento		100
Riverside Village Maintenance District	Sacramento		115
Sierra Oaks Unit No. 1 Maintenance District	Sacramento		65
Sierra Oaks Units 2 and 3 Maintenance District	Sacramento		80

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Sacramento County—Continued			
Community Services Districts			
San Juan Suburban Water District	Orangevale, etc.	(Sells at wholesale)	
Special Water Service Districts			
Sacramento County Water Agency		(Sells at wholesale)	
San Joaquin County			
Municipal Waterworks			
Lodi	Lodi		4,479
Manteca	Manteca		1,250
Ripon	Ripon		538
Tracy	Tracy		2,225
Commercial Water Companies			
California Water Service Company	Stockton		27,700
Escalon Water and Light Company	Escalon		490
Mayfair Water Company	Stockton		131
Oak Park Court Water Company	Stockton		63
Stockton Land Association, The	Stockton		263
West Lane Heights Water Company	Stockton		137
Mutual Water Companies			
Fremont Irrigation Association	Tracy	667	
Independent Mutual Water Company	Tracy	1,286	
Munro Orchard Water Company	Stockton	413	
Mutual Water Company No. 1 and No. 3	Banta		44
Paradise Mutual Water Company	Tracy	864	
San Joaquin River Water Users Company	Manteca	1,415	
Silva Gardens Mutual Water Company	Stockton		2
Thornton Water Company	Thornton	1,500	
Union Island Mutual Water Company	Tracy	1,400	
Woodbridge Water Users Association	Woodbridge	7,500	
Woods Irrigation Company	Stockton	6,298	
County Water Districts			
Ripon County Water District	Ripon		550
San Joaquin County Water District No. 1	Lockeford		190
San Joaquin County Water District No. 2	Victor		77
Irrigation Districts			
Banta-Carbona Irrigation District	Vernalis	14,491	
Byron-Bethany Irrigation District	Byron	(See Contra Costa County)	
Naglee-Burke Irrigation District	Tracy	2,455	
Oakdale Irrigation District	Oakdale	(See Stanislaus County)	
South San Joaquin Irrigation District	Manteca	63,842	
Tracy-Clover Irrigation District	Tracy	400	
West Side Irrigation District	Tracy	11,826	
West Stanislaus Irrigation District	Westley	(See Stanislaus County)	
Woodbridge Irrigation District	Lodi	15,177	
Reclamation Districts			
Reclamation District 404	Stockton	860	
Reclamation District 2023	Rio Vista	3,150	
Reclamation District 2027	Stockton	5,400	
Reclamation District 2028	Stockton	5,624	
Reclamation District 2030	Stockton	4,400	100
Reclamation District 2041	Stockton	1,205	
Reclamation District 2042	Stockton	2,200	
Reclamation District 2058	Banta	7,990	14
Reclamation District 2062	Banta	3,939	9
Reclamation District 2064	Manteca	3,000	
Reclamation District 2072	Stockton	1,856	
Reclamation District 2074	Stockton		1
Reclamation District 2075	Ripon	2,773	
Water Districts			
Plain View Water District	Tracy	4,147	

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
San Joaquin County—Continued			
Municipal Improvement Districts and County Maintenance Districts			
Colonial Heights Maintenance District	Stockton		150
Lincoln Village Maintenance District	Stockton		250
Water Conservation Districts			
North San Joaquin Water Conservation District	Lodi	40,000	5,000
Stockton and East San Joaquin Water Conservation District	Stockton	42,700	
Shasta County			
Municipal Waterworks			
Redding	Redding		3,654
Commercial Water Companies			
Anderson Water Company	Anderson		497
Castella Water Works	Castella		41
Cottonwood Water Works	Cottonwood		116
Fall River Mills Water Company	Fall River Mills		185
French Gulch Ditch System	French Gulch		
Happy Valley Water Company	Olinda	5,000	10
Johnson Park Water Works	Burney	5	54
Mutual Water Companies			
Bee Creek Ditch and Water Company	Ono	250	5
Bunker Hill Water System	Burney		8
Burney Subdivision Water Association No. 1	Burney		17
Excelsior Ditch	Oak Run	85	
Grover and Wilcox Ditch	Anderson	150	
Millville Ditch Company, Inc.	Millville	175	
Townsend Flat Water Ditch Company	Redding	340	
Verde Vale Water Company	Anderson	20	50
Wren Water System	Cottonwood		6
County Water Districts			
Buckeye County Water District	Redding		125
Burney County Water District	Burney	40	427
Irrigation Districts			
Anderson-Cottonwood Irrigation District	Anderson	19,320	
Public Utility Districts			
Enterprise Public Utility District	Redding		125
Shasta Dam Area Public Utility District	Project City		950
Summit City Public Utility District	Summit City		116
Sierra County			
Municipal Waterworks			
Loyalton	Loyalton		263
Commercial Water Companies			
Bachels Water Right	Goodyear Bar		10
Mutual Water Companies			
Sierra Valley Water Company	Sierraville	14,500	
Public Utility Districts			
Downieville Public Utility District	Downieville		100
Siskiyou County			
Municipal Waterworks			
Mount Shasta	Mount Shasta		840
Commercial Water Companies			
Dunsmuir Water Corporation	Dunsmuir		1,254
Shasta Retreat Water System	Dunsmuir		58
Mutual Water Companies			
McCloud Water Supply	McCloud		600
Pondosa Water Supply	Pondosa		60

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Solano County			
Municipal Waterworks			
Rio Vista	Rio Vista		591
Commercial Water Companies			
California Water Service Company	Dixon		661
Pacific Gas and Electric Company	Vacaville		794
Mutual Water Companies			
Collinsville Water Supply	Collinsville		16
Davis Ranches	Winters	660	3
Rockville Water Supply	Fairfield		20
Irrigation Districts			
Solano Irrigation District	Vacaville	17,283	
Reclamation Districts			
Reclamation District 501	Rio Vista	11,962	
Reclamation District 999	Walnut Grove	(See Yolo County)	
Reclamation District 2060	Rio Vista	4,301	
Reclamation District 2068	Dixon	9,913	
Special Water Service Districts			
Solano County Flood Control and Water Conservation District		(Sells at wholesale)	
United States Bureau of Reclamation Projects			
Solano Project		(Sells at wholesale)	
Stanislaus County			
Municipal Waterworks			
Modesto	Modesto		7,500
Oakdale	Oakdale		1,600
Turlock	Turlock		2,488
Commercial Water Companies			
Bumgardner, George, Water Company	Modesto		1,467
Ceres Water Works	Ceres		631
College Gardens Water Company	Modesto		163
Crows Landing Water Company	Crows Landing		130
Del Este Water Company	Empire, Modesto, Salida, Turlock, Waterford		6,413
Denair Water Works	Denair		170
El Solyo Water Company	Westley	4,000	
Keyes Water Company	Keyes		192
Knights Ferry Water Company	Knights Ferry	3	21
McQuary Water Company	Ceres		75
Mission Manor Water Company	Modesto-Ceres		35
Moore, Joseph A., Water Company	Modesto		296
Morrow Water Company	Ceres		56
Newman Water Works Company	Newman		603
Osterberg Water Works	Modesto		460
Patterson City Water Company	Patterson		709
Riverbank Water Company	Hughson, Riverbank		1,368
Vincent Water Company	Ceres		135
Mutual Water Companies			
Blewett Mutual Water Company	Vernalis	1,064	
El Terino Mutual Water Company	Modesto		22
Patterson Farm Labor Camp	Patterson		144
Patterson Water Company	Patterson	13,910	
Twin Oaks Irrigation Company	Patterson	2,400	
Westley Farm Labor Camp	Westley		248
White Lake Mutual Water Company	Westley	1,408	
Irrigation Districts			
Central California Irrigation District		(See Merced County)	
Modesto Irrigation District	Modesto	70,038	
Oakdale Irrigation District	Oakdale	56,918	
Turlock Irrigation District	Turlock	163,735	
Waterford Irrigation District	Waterford	6,700	
West Stanislaus Irrigation District	Westley	24,861	

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Stanislaus County—Continued			
Reclamation Districts			
Reclamation District 2031	Modesto	3,000	10
Water Districts			
Davis Water District	Newman	100	
Del Puerto Water District	Patterson	3,408	
Foothill Water District	Newman	1,123	
Hospital Water District	Westley	5,260	
Kern Canon Water District	Westley	1,200	
Orestimba Water District	Crows Landing	4,320	
Rock Creek Water District	Farmington	700	
Salado Water District	Patterson	2,220	
Sunflower Water District	Crows Landing	500	
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at	wholesale)
Sutter County			
Municipal Waterworks			
Live Oak	Live Oak		211
Yuba City	Yuba City		3,102
Commercial Water Companies			
Sutter Butte Canal Company		(See Butte County)	
Mutual Water Companies			
Butte Slough Irrigation Company	Colusa	4,712	
Garden Highway Mutual Water Company	Yuba City	3,100	
Hillcrest Mutual Water Company	Yuba City		15
Meridian Farms Water Company	Meridian	8,284	
Natomas Central Mutual Water Company		(See Sacramento County)	
Natomas Riverside Mutual Water Company		(See Sacramento County)	
Sutter Mutual Water Company	Robbins	47,785	
Tisdale Irrigation and Drainage Company	Grimes	1,155	
Reclamation Districts			
Reclamation District 817	Wheatland	(See Yuba County)	
Reclamation District 1004		(See Colusa County)	
Water Districts			
Oswald Water District	Yuba City	640	
Sutter Extension Water District		10,683	
Municipal Improvement Districts and County Maintenance Districts			
Hillcrest Tract Improvement District	Yuba City	13	15
Tehama County			
Municipal Waterworks			
Corning	Corning		850
Red Bluff	Red Bluff		1,575
Tehama	Tehama		75
Commercial Water Companies			
Gerber Water Works	Gerber		215
Las Flores Water Works	Las Flores		30
Los Molinos Water Works	Los Molinos		166
Mineral Water System	Mineral		50
Mutual Water Companies			
Bend Water Users	Bend	360	
Coneland Water Company	Los Molinos	350	
Corning Irrigation Company	Corning	1,000	
Los Molinos Mutual Water Company	Los Molinos	18,000	
Stanford Vina Ranch Irrigation Company	Vina	5,412	
Tehama County—Continued			
Irrigation Districts			
Anderson-Cottonwood Irrigation District	Anderson	(See Shasta County)	
Deer Creek Irrigation District	Corning	1,890	
El Camino Irrigation District	Tehama	4,500	
Tulare County			
Municipal Waterworks			
Dinuba	Dinuba		1,595
Exeter	Exeter		1,264
Lindsay	Lindsay		1,650
Porterville	Porterville		2,163
Tulare	Tulare		3,838
Woodlake	Woodlake	300	700
Commercial Water Companies			
Berrysen Water Company	Visalia		47
California Water Service Company	Visalia		5,514
Cook's Water System	Poplar		171
Ducor Water Company	Ducor		41
Farmersville Water Company	Farmersville	35	90
Foothill Ditch Company	Exeter	2,100	
Ivanhoe Water Company	Ivanhoe		479
Lemon Cove Water Company	Lemon Cove		33
Marshall Water Company	Farmersville		
North Tulare Water Company	Tulare		70
Phillips Water Company	Earlimart		30
Pine Flat Water Company	California Hot Springs		87
Wilson Water System	Earlimart		312
Mutual Water Companies			
Alta Vista Water Company	Porterville	185	
Antelope Heights Water and Irrigating Company	Woodlake	380	
Ball and Harris Ditch Company	Porterville	480	
Bedel Mutual Water Company	Visalia		36
Berrysen Mutual Water Company	Visalia		47
Big Stump Trailer Court	Porterville		12
Blachern Water Company	Porterville	50	
Bliss Ditch Company	Tulare		64
Bonnie Brae Ditch	Exeter	1,375	
Brundage Ditch	Three Rivers	132	
Bynum, Roy	Porterville		5
Campbell Moreland Ditch Company	Porterville	1,205	
Canby Mutual Water Company	Canby		19
Cedar Slope Mutual Water Company	Porterville		14
Central Mutual Water Company	Porterville	20	24
Churchill Camp	Tulare		20
Consolidated Peoples Ditch Company	Exeter	20,000	
Copo De Oro Water Company	Porterville	109	
Cottonwood Ditch Association	Ivanhoe	504	
Covina-Ducor Water Company	Ducor	80	
Deer Creek Water Company	Porterville	100	3
Dennison Ditch Company	Springville		
Douglas Drive and Belleview	Porterville		12
Earlimart Mutual Water Company, Inc.	Earlimart		160
East Orosi Water System	Orosi		40
Elderwood Water Company	Woodlake	167	
Elk Bayou Ditch Company	Tulare	4,000	40
Evans Ditch Company	Visalia	2,670	
Fairways Tract Water Company	Porterville	10	2
Farmers Ditch Company	Tulare	8,500	100
Fleming Ditch Company	Visalia	1,290	
Garden City Irrigation Company	Porterville	177	
Gilliam-McGee Ditch	Porterville	308	
Goshen Ditch Company	Goshen	530	
Graham and Osborne Ditch Company	Springville	500	
Grant, Martin, Cabins	Tulare		30
Hamilton Ditch	Woodlake	170	
Hawkeye Ditch Company	Lemon Cove	300	
Hillside Mutual Water Company	Woodlake	85	
Hilo Water Company	Porterville	90	
Honora Water Company	Lemon Cove	500	
Hubbs and Miner Ditch	Porterville	1,810	
Jack Ranch Summer Resort	Posey	5	16

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Tulare County—Continued			
Mutual Water Companies—Continued			
Jennings Ditch Water Company	Visalia	2,300	
Kaweah Lemon Company	Lemon Cove	650	23
Kaweah River Acres Mutual Water Company	Three Rivers		3
Kelly Ditch Company	Three Rivers	150	
Laspina Mutual Water Company	Tulare	10	35
Lemon Cove Ditch Company	Lemon Cove	1,200	
Lindsay Heights Water Company	Lindsay	183	
Linnell Housing Water Supply	Linnell	25	170
Little Pioneer Ditch Company	Woodville	209	
Lois Water Company	Porterville	20	1
Long's Canal	Woodlake	325	
Lovelace Ditch Company	Three Rivers	100	
Marks-Rice Ditch	Lemon Cove	100	
Matheny Mutual Water Company	Tulare	2	8
Mathews Ditch Company	Visalia	2,000	
Miami Well Company, Inc.	Porterville	120	5
Modoc Ditch Company	Visalia	5,000	
Monache Water Company	Porterville	171	
Mount Whitney Ditch and Water Company	Springville	300	
North Tulare Subdivision	Tulare		72
Oakes Ditch Company	Visalia	920	
Oro Water Company	Porterville	59	
Persian Ditch Company	Tulare	3,350	
Pioneer Water Company	Porterville	1,738	
Pleasant Valley Canal Company	Porterville	700	
Poplar Irrigation Company	Porterville	8,308	
Porter Slough Ditch Company	Porterville	1,038	
Redbanks Mutual Water Company	Woodlake	800	
Rhodes and Fine Ditch Company	Porterville	1,034	
Richgrove Mutual Water Company	Richgrove		150
Riverside Water Company	Porterville	100	
River Way Ranch	Three Rivers	12	
Rosedale Water Company	Porterville	172	
Saint Johns Ditch Company	Visalia	590	
Saint Johns River Mutual Water Company	Woodlake	558	1
South Tule Independent Ditch Company	Porterville	500	
Stivers Water Agency	Woodlake		10
Stockton Ditch Company	Woodville	800	
Sunnyside Water Company	Porterville	145	
Sweeney Ditch	Woodlake	165	
Thermal Water Company	Ducor	182	
Tipton Mutual Water Company	Tipton		225
Tooleville Non-Profit Water System	Tulare		65
Tract 99 Mutual Water Company	Porterville		134
Tulare Irrigation Company	Visalia	3,000	
Tule River Riparianists, Inc.	Porterville	5,909	
Uphill Ditch Company	Visalia	3,000	
Visalia and Kaweah Water Company	Visalia	10,000	
Wallace Ranch Water Company	Lemon Cove	1,000	
Watson Ditch Company	Visalia	3,400	
Williams Mutual Water Company	Porterville	40	24
Woodlake Valley Mutual Water Company	Woodlake	135	
Wutchumna Water Company	Visalia	30,000	
Yettem Seville Water Association	Yettem	3,290	
Irrigation Districts			
Alpaugh Irrigation District	Earlimart	8,131	264
Alta Irrigation District	Reedley	110,103	
Consolidated Irrigation District	Selma	(See Fresno County)	
Delano-Earlimart Irrigation District	Earlimart	8,566	
Exeter Irrigation District	Exeter	11,000	
Hills Valley Irrigation District	Orange Cove	(See Fresno County)	
Ivanhoe Irrigation District	Ivanhoe	9,762	
Lindmore Irrigation District	Strathmore	21,100	
Lindsay-Strathmore Irrigation District	Lindsay	9,465	600
Lower Tule River Irrigation District	Pixley	74,685	
Tulare County—Continued			
Irrigation Districts—Continued			
Orange Cove Irrigation District	Orange Cove	(See Fresno County)	
Porterville Irrigation District	Porterville	14,351	
Saucelito Irrigation District	Terra Bella	15,965	
Stone Corral Irrigation District	Orosi	4,045	
Terra Bella Irrigation District	Terra Bella	3,018	484
Tulare Irrigation District	Tulare	66,313	
Vandalia Irrigation District	Porterville	1,100	42
Public Utility Districts			
Cutler Public Utility District	Cutler		225
Strathmore Public Utility District	Strathmore		250
Woodlake Public Utility District	Woodlake	300	700
Woodville Public Utility District	Woodville		160
Community Services Districts			
London Community Service District	Dinuba		31
Lovell Community Services District	Visalia	3,500	
United States Bureau of Reclamation Projects			
Central Valley Project		(Sells at wholesale)	
Tuolumne County			
Commercial Water Companies			
Pacific Gas and Electric Company	Jamestown, Sonora, Tuolumne		1,798
Mutual Water Companies			
Lilac Terrace Subdivision	Sonora		12
Long Barn Property Owners Corporation	Long Barn		90
Pinecrest Permittees Association	Pinecrest		387
Schoettgun Water Supply	Columbia	25	9
Slide Inn Mutual Water Association	Long Barn		30
County Water Districts			
Tuolumne County Water District No. 1	Twain Harte		692
Yolo County			
Municipal Waterworks			
Davis	Davis		1,290
Winters	Winters		418
Woodland	Woodland		2,998
Commercial Water Companies			
Clear Lake Water Company	Esparto, etc.	26,090	
Washington Water and Light Company	Broderick, Bryte, West Sacramento		2,129
West Sacramento Water Company	West Sacramento		412
Mutual Water Companies			
Capay Valley Ditch Company	Capay	1,280	
Linden Acres Water Supply	West Sacramento		82
Rumsey Ditch Company	Rumsey	158	
Sweetwater Company	Dixon	2,440	
County Waterworks Districts			
Yolo County Waterworks District No. 1	Esparto		183
Reclamation Districts			
Reclamation District 108	Dunnigan	(See Colusa County)	
Reclamation District 150	Sacramento	5,000	83
Reclamation District 307	Clarksburg	6,000	
Reclamation District 999	Clarksburg	23,335	300
Reclamation District 2035	Woodland	7,418	
Reclamation District 2068	Dixon	(See Solano County)	

WATER SERVICE AGENCIES, CENTRAL VALLEY AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Yuba County			
Municipal Waterworks			
Wheatland	Wheatland		300
Commercial Water Companies			
California Water Service Company			2,651
Camptonville Water Service	Camptonville	20	50
Dententers Water Service	Marysville		180
Linda Center Water System	Marysville		52
Yuba Investment Company	Browns Valley		7
Mutual Water Companies			
Challenge Water Supply	Challenge		65
Hallwood Irrigation Company	Marysville	7,036	
Plumas Mutual Water Company	Marysville	1,244	
Yuba County—Continued			
Irrigation Districts			
Browns Valley Irrigation District	Browns Valley	3,300	
Camp Far West Irrigation District	Sheridan	(See Placer County)	
Cordua Irrigation District	Marysville	5,090	
Reclamation Districts			
Reclamation District No. 10	Marysville	9,800	
Reclamation District 817	Wheatland	4,000	40
Water Districts			
Wheatland Water District	Wheatland	8,000	
Public Utility Districts			
Olivehurst Public Utility District	Marysville		686

WATER SERVICE AGENCIES, LAHONTAN AREA

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
El Dorado County			
Commercial Water Companies			
Globin, Frank	Al Tahoe / Bijou Pines		304
Lakeside Lodge Utility	Stateline		27
Pinewood Water Company	Bijou		14
Tahoe Cedars Water Company	Tahoma		92
Tahoe Sierra Water Company	Bijou	228	68
Mutual Water Companies			
Camp Richardson Water Supply	Camp Richardson		3
Fallen Leaf Mutual Water Company	Fallen Leaf		50
Lakeside Park Association	Placerville		95
Meeks Bay Resort	Meeks Bay		60
Tahoe Fifty Subdivision	Tahoe	18	
Water Districts			
Rubicon Water District	Rubicon Beach		10
Inyo County			
Municipal Waterworks			
Bishop	Bishop		600
Commercial Water Companies			
Independence Water Company	Independence		296
Lone Pine Water Company	Lone Pine		430
Smith, A. T., Water Company	Keeler		37
Mutual Water Companies			
Bishop Creek Ditch Company	Bishop	10	
Bishop Creek Water Association	Bishop	8,000	
Tecopa Water Supply	Tecopa		30
Kern County			
Commercial Water Companies			
Inyokern Water Service	Inyokern		140
Randsburg Water Company	Randsburg / Johannesburg		259
Ridgecrest Water Supply	Ridgecrest		468
Rocket Town Water Company, Inc.	Ridgecrest		2
Rosamond Water Company	Rosamond		134
Mutual Water Companies			
China Lake Mutual Water Company	Ridgecrest		8
Citizens Mutual Water Company	Boron	600	84
Desert Sands Water Cooperative, Inc.	Ridgecrest		9
Ridgecrest Mutual Water Company	Ridgecrest		125
Surplus Water Company	Boron		68
Valley Acres Mutual Water Company	Inyokern	25	9
Community Services Districts			
Boron Community Services District	Boron		62
Lassen County			
Commercial Water Companies			
California-Pacific Utilities Company	Susanville		1,871
Mutual Water Companies			
Lassen Irrigation Company	Standish	5,000	
Irrigation Districts			
Tule Irrigation District	Susanville		
Los Angeles County			
Commercial Water Companies			
B. V. Water Company, Inc.	Lancaster-Palmdale		196
Bagstad, Chester C.	Littlerock		12
Mutual Water Companies			
Altura Tract Association	Palmdale	30	22
Antelope Center Water Association	Palmdale	40	30
Antelope Mutual Water Company	Lancaster	5	25
Antelope Park Mutual Water Company	Lancaster		42
Averydale Mutual Water Company	Lancaster	120	38
Bellview Mutual Water Company	Lancaster		43
Big Rock Mutual Water Company	Llano	60	
Los Angeles County—Continued			
Mutual Water Companies—Continued			
Calivalli Mutual Water Company	Littlerock	1,225	
Deep River Water Company	Palmdale		16
Desacres Water Company	Palmdale		15
El Dorado Mutual Water Company	Palmdale		200
Fifty-eight Mutual Water Company	Littlerock	150	
Lake Elizabeth Mutual Water Company	Lancaster		8
Lancaster Water Company	Lancaster		15
Land Projects Mutual Water Company	Lancaster	50	45
Landale Mutual Water Company	Lancaster		15
Leona Valley Mutual Water Company	Palmdale		78
Mountain View Farms Water Company	Lancaster	300	18
Palmdale Ranchos Mutual Water Company	Palmdale	37	47
Palm Ranch Mutual Water Company	Lancaster	1,040	325
Pearblossom Heights Mutual Water Company, Inc.	Pearblossom	11	95
Rock Creek Water Corporation	Pearblossom	500	
Section 29 Mutual Water Company	Lancaster	180	5
Shadow Mountain Mutual Water Company	Palmdale	50	16
Sierra Mutual Water Company, Inc.	Lancaster		12
Sunnyside Farms Mutual Water Company	Lancaster	180	164
Sunnyvale Mutual Water Company	Littlerock	150	24
West Side Park Mutual Water Company	Palmdale		53
White Fence Farms Mutual Water Company	Lancaster	640	41
White Fence Farms Mutual Water Company No. 2	Lancaster	640	25
Wilsona Gardens Mutual Water Company	Lancaster		11
Irrigation Districts			
Littlerock Creek Irrigation District	Littlerock	1,036	227
Palmdale Irrigation District	Palmdale	180	800
County Waterworks District			
Los Angeles County Waterworks District No. 4 (Lancaster)	Lancaster	200	2,175
Los Angeles County Waterworks District No. 23 (Lancaster Heights)	Lancaster	25	139
Modoc County			
Mutual Water Companies			
Patterson Water Company	Cedarville	1,750	
Mono County			
Mutual Water Companies			
Antelope Valley Mutual Water Company	Coleville	6,129	
Sierra Land and Water Company	Leevining	12,000	
Public Utility Districts			
June Lake Fire District	June Lake		1,000
Nevada County			
Commercial Water Companies			
Sanders and Gebhart Water Company	Truckee		22
Public Utility Districts			
Truckee Public Utility District	Truckee		300
Placer County			
Commercial Water Companies			
Carnelian Bay Water Company	Carnelian Bay		65
Fulton Water Company	Lake Forest		40
Lake Forest Water Company	Lake Forest		60
Linkford Water Company	Tahoe Vista		8
Madden Creek Water Company	Homewood		98
Mountain Springs Water Company	Agate Bay View		18
Tahoe Cedars Water Company	Tahoma		
Tahoe Tavern Heights Water System	Tahoe Tavern		11

WATER SERVICE AGENCIES, LAHONTAN AREA—Continued

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Placer County—Continued			
Commercial Water Companies—Continued			
Tahoe Park Water System	Tahoe City		123
Tahoe Pines Water Company	Tahoe Pines		84
Mutual Water Companies			
Brockway Water Company	Brockway		368
Cedar Flat Improvement Association	Tahoe City		100
Lake Forest Unit No. 3 Property Owners Association	Lake Forest		22
Murray Water Company	Tahoe Vista		13
Ridgewood Water System	Tahoe City		28
Short Water System	Tahoe City		4
Squaw Valley Mutual Water Company	Tahoe City	300	87
Sugar Bowl Mutual Water Company	Truckee		16
Timberland Subdivision Water System	Tahoe City		33
Ward Creek Water Company	Tahoe City		15
Ward Well Water Company	Tahoe City		51
San Bernardino County			
Commercial Water Companies			
Apple Valley Ranchos Water Company	Apple Valley		233
Arrowhead Manor Water Company	Lake Arrowhead		88
Arrowhead Utility Company	Lake Arrowhead		975
Hesperia Water Company	Hesperia		101
Lake Brook Park Water System	Lake Brook Park	160	263
Lake Gregory Water Company	Lake Gregory		387
Meadowbrook Water Association	Lake Arrowhead		77
Pacific Water Company	Arrowhead View Victorville Wags Tract		490
Randsburg Water Company	Red Mountain	(See Kern County)	
Running Springs Forest Water Company	Running Springs		9
Searles Domestic Water Company	Argus Point of Rocks Trona		792
San Bernardino County—Continued			
Commercial Water Companies—Continued			
Smithson Springs Water Company	Desert Springs		54
Southern California Water Company	Barstow		1,829
Sturnacle Water Company	Barstow		10
Swarthout Valley Water Company	Wrightwood		558
Westside Water Company	Barstow		140
Yermo Water Company	Yermo		60
Mutual Water Companies			
Adelanto Mutual Water Company	Adelanto		400
Agua Fria Mutual Service Company	Agua Fria		70
Alpine Water Users Association	Twin Peaks		300
Arrow Bear Mutual Water Company, Inc.	Arrowbear		150
Arrowhead Highlands Mutual Service Company	Arrowhead Highlands		100
Arrowhead View Water Corporation	Blue Jay		121
Arrowhead Villas Mutual Service Company	Sky Forest		263
Crestline Village Mutual Service Company	Crestline		1,700
Desert Knolls Mutual Water Company	Victorville	190	30
Green Valley Mutual Water Company	Green Valley Lake		325
Mountain Pioneer Mutual Water Company	Rimforest		18
Sheep Creek Water Company	Phelan	150	30
Valley of Enchantment Mutual Water Company	Crestline		400
County Water Districts			
Victorville County Water District	Victorville		806
County Waterworks Districts			
San Bernardino County Waterworks District No. 2	Adelanto		223

WATER SERVICE AGENCIES, COLORADO DESERT AREA

Name of water agency	Location, in or near	Area irrigated, in acres	Number of domestic services
Imperial County			
Municipal Waterworks			
Brawley	Brawley		2,171
Calexico	Calexico		1,275
El Centro	El Centro		2,937
Holtville	Holtville		700
Imperial	Imperial		
Westmorland	Westmorland		360
Commercial Water Companies			
Seeley Water System	Seeley		85
Southern California Water Company	Calipatria, Niland		568
Mutual Water Companies			
Ocotillo Mutual Water Company	El Centro		5
Winterhaven Water Company	Winterhaven		175
Irrigation Districts			
Bard Irrigation District	Bard	5,400	
Imperial Irrigation District	El Centro	391,714	
Palo Verde Irrigation District	Blythe	(See Riverside County)	
Public Utility Districts			
Heber Public Utility District	Heber	2,080	
United States Bureau of Reclamation Projects			
Yuma Project	Yuma	8,559 (Also sells at wholesale)	
Riverside County			
Municipal Waterworks			
Blythe	Blythe		900
Coachella	Coachella		573
Indio	Indio		1,077
Commercial Water Companies			
Bubbling Wells Water System, Inc.	Desert Hot Springs		2
Cabazon Water Company	Cabazon	20	133
Cathedral City Water Company	Cathedral City		374
City Water Company of Banning, California	Banning		2,381
Garnet Gardens Water Company	Garnet		48
Mecca Water and Development Company	North Palm Springs		59
Midway Water Service	Banning		40
Palm Desert Water Company			145
Palm Springs Outpost Water Company	Palm Springs		19
Palm Springs Water Company	Palm Springs		3,018
Rancho Mirage Water Company	Rancho Mirage		160
Thermal Water System	Thermal		88
Thunderbird Water Company	Palm Springs	120	17
Mutual Water Companies			
Acres Mutual Water Company	Indio		69
Auroratowne Mutual Water Company	Auroratowne		100
Banning Heights Mutual Water Company	Banning	635	35
Banning Heights Water Company	Banning	672	
Banning Water Company	Banning	1,000	2,260
Cathedral Canon Mutual Water Company	Cathedral City	50	
Country Club Water Company	Palm Springs		1
Cowgill Mutual Water Company	Thermal	80	2
Date Development Water Company	Coachella	160	1
Dateland Mutual Water Company	Indio	80	2
Date Palm Road Mutual Water Company	Palm Springs		8
Deglet Noor Mutual Water Company	Indio	295	
Del Sol Mutual Water Company	Indio	160	22
Desert Date Gardens Irrigation Company	Indio	33	8
Dos Palmas Mutual Water Company	Desert Hot Springs		12
Flying-H Mutual Water Company	Cathedral City		5
Riverside County—Continued			
Mutual Water Companies—Continued			
Hidden Springs Ranch Mutual Water Company	Thousand Palms	1,400	12
Los Ranchitos Mutual Water Company, Ltd.	Cathedral City	25	5
North Indio Mutual Water Corporation	Indio		98
One Twenty Mutual Water Company	Indio		24
Palm Dell Mutual Water Company	Palm Desert		4
Palm Desert Water Company	Indio		127
Palm Springs Vista Mutual Water Company	Palm Springs	40	1
Panorama Mutual Water Company	Palm Desert	40	15
Rancho Myoma Mutual Water Company	Indio	100	3
Rancho Vista Mutual Water Company	Palm Springs	120	350
San Jacinto Mutual Water Company	Indio	80	7
Santa Carmelita Mutual Water Company	Indio		162
Shangri-la Palms Mutual Water Company	Palm Springs	113	75
Whitewater Mutual Water Company	Palm Springs	725	
Wontam Mutual Water Company	Cathedral City	130	127
County Water Districts			
Coachella Valley County Water District	Indio	27,312	
Desert Hot Springs County Water District	Desert Hot Springs		468
Irrigation Districts			
Palo Verde Irrigation District	Blythe	59,571	
Community Services Districts			
Palm Desert Community Services District	Palm Village	220	159
San Bernardino County			
Municipal Waterworks			
Needles	Needles		1,024
Commercial Water Companies			
Abell Water Company	Twentynine Palms		347
Joshua Tree Service Company	Joshua Tree		207
Pacific Water Company	Morongo-Twentynine Palms		902
Sunfair Water Company	Joshua Tree		50
Vidal Water Company	Vidal		6
Yucca Water Company, Ltd.	Yucca Valley		243
Mutual Water Companies			
Condor Mutual Water Company, Inc.	Twentynine Palms		28
Desert Rancho Mutual Water Company	Joshua Tree		6
Hesperia Water Company	Hesperia	75	109
Lucerne Valley Mutual Water Company	Lucerne Valley		8
Mesa Land and Water Company	Joshua Tree		2
Paradise Valley Mutual Water Company	Paradise Valley	300	5
San Diego County			
Commercial Water Companies			
Borrego Springs Water Company	Borrego Valley		66
Jacumba Water Company	Jacumba		110
Live Oaks Spring Water and Power Company	Pine Valley		86
Mutual Water Companies			
Borrego Village Mutual Water Company	Borrego Springs	40	10
Rancho Borrego Mutual Water Company	Borrego Springs		1
Tub Canyon Mutual Water Company	Borrego Valley		67

APPENDIX C

DESCRIPTION OF HYDROGRAPHIC UNITS

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DESCRIPTION OF HYDROGRAPHIC UNITS

NORTH COASTAL AREA

Hydrographic Unit 1—Tule Lake—This unit consists largely of the California portion of areas tributary to the Klamath River Basin, above the U. S. Geological Survey gaging station near Copco. The portion of the natural watershed of the Klamath River in this unit is not large. A more important segment consists of the California portion of the Lost River drainage basin, which has been artificially connected with the Klamath River by a canal for the purpose of reclaiming the bed of Tule Lake. Furthermore, certain other entirely self-contained basins are included in this unit, since these would drain into the Klamath River under conditions of extremely high runoff. These are Butte Valley, Red Rock Basin, and Oklahoma Basin.

Hydrographic Unit 2—Shasta Valley—This unit consists of the drainage basin of the Shasta River above the U. S. Geological Survey gage near Yreka, 0.5 mile above its mouth.

Hydrographic Unit 3—Scott Valley—This unit consists of that portion of the Scott River Basin above the U. S. Geological Survey gage near Fort Jones.

Hydrographic Unit 4—Upper Klamath—This unit consists of the California portion of the Klamath River Basin between the U. S. Geological Survey gaging stations near Copco and near Seiad Valley, with the exception of the Shasta and Scott River drainage basins above the U. S. G. S. gaging stations on those streams.

Hydrographic Unit 5—Trinity—This unit consists of the entire drainage basin of the Trinity River above its mouth.

Hydrographic Unit 6—Klamath—This unit consists of the California portion of the Klamath River Basin downstream from Seiad Valley, with the exception of the drainage basin of the Trinity River.

Hydrographic Unit 7—Rogue—This unit consists of those lands in California draining northward into the Rogue and Winchuck Rivers in Oregon, together with the drainage basin of Gilbert Creek flowing directly into the Pacific Ocean north of the Smith River.

Hydrographic Unit 8—Del Norte—This unit includes the California portion of the Smith River Basin, as well as minor drainage basins directly tributary to the Pacific Ocean between the Smith and Klamath River Basins, including Jordan, Elk, Cushing, Nickel, Damnation, and Wilson Creeks.

Hydrographic Unit 9—Redwood Creek—This unit includes the drainage basin of Redwood Creek, as well as the drainage basins of smaller streams between the Klamath River and Redwood Creek Basins, including Ossagon, Butler, Home, and Squashan Creeks.

Hydrographic Unit 10—Mad River—This unit includes the drainage basin of the Mad River, as well as the drainage basins of smaller streams directly tributary to the Pacific Ocean between the Redwood Creek and Mad River Basins, including Freshwater, Stone, and Big Lagoons (Maple Creek), Luffenholz Creek, Little River, and Strawberry and Widow White Creeks, as well as the City of Arcata.

Hydrographic Unit 11—Upper Eel—This unit consists of that portion of the drainage basin of the Eel River and its tributaries upstream from the U. S. Geological Survey gage at Scotia.

Hydrographic Unit 12—Humboldt—This unit consists of the Eel River drainage basin below Scotia, including that of the Van Duzen River, areas tributary to Humboldt Bay from the drainage basin of James Creek to that of Salmon Creek, and basins of other streams draining directly into the Pacific Ocean between the Mad and Mattole River Basins, from Fleenes Creek on the north to Peter B Gulch on the south, with the exception of the City of Arcata.

Hydrographic Unit 13—Mattole—This unit includes the drainage basin of the Mattole River, as well as the basins of the Fourmile Creek group, consisting of streams directly tributary to the ocean south of the Mattole River from Fourmile Creek to Quail Gulch.

Hydrographic Unit 14—Mendocino Coast—This unit consists of several river and stream group basins, from the basin of Jackass Creek in the Tenmile River group on the north to that of Russian Gulch in the Stewart's Point group on the south.

Hydrographic Unit 15—Russian River—This unit consists of the entire drainage basin of the Russian River to its mouth.

Hydrographic Unit 16—Bodega—This unit consists of the watersheds of minor streams entering either the Pacific Ocean or Bodega or Tomales Bays, between the Russian River and the south drainage boundary of Grand Canyon near Point Reyes Station.

SAN FRANCISCO BAY AREA

Hydrographic Unit 1—Marin-Sonoma—This unit consists of those drainage basins in Marin and Sonoma Counties lying within the San Francisco Bay Area from that of Tomasini Canyon, a tributary of

Lagunitas Creek, to and including that of Sonoma Creek.

Hydrographic Unit 2—Napa Valley—This unit consists of the drainage basin of the Napa River.

Hydrographic Unit 3—Solano—This unit consists of that portion of the San Francisco Bay Area east of the Napa River drainage basin and north of Suisun Bay, from the drainage basin of an unnamed stream tributary to Glen Cove on the west to that of Montezuma Slough on the east.

Hydrographic Unit 4—Contra Costa—This unit consists of that portion of Contra Costa County draining directly into San Francisco, San Pablo, and Suisun Bays, from El Cerrito Creek to the basin of Kirker Creek, inclusive.

Hydrographic Unit 5—Livermore Valley—This unit consists of the drainage basin of Alameda Creek above the U. S. Geological Survey gaging station near Niles.

Hydrographic Unit 6 — Alameda-Bayside — This unit includes that portion of Alameda County directly bordering on San Francisco Bay, from El Cerrito Creek on the north to Scott Creek on the south, including that portion of the drainage basin of Alameda Creek below the U. S. Geological Survey gaging station near Niles. The portions of the drainage basins of San Leandro and San Lorenzo Creeks in Contra Costa County are also included in this unit.

Hydrographic Unit 7—Santa Clara Valley—This unit consists of all of Santa Clara County in the San Francisco Bay Area, except the portion tributary to Alameda Creek.

Hydrographic Unit 8—San Mateo-Bayside—This unit consists of that portion of San Mateo County draining into San Francisco Bay.

Hydrographic Unit 9—San Mateo-Coastal—This unit includes that portion of San Mateo County draining into the Pacific Ocean, south to and including the drainage basin of Pescadero Creek. This unit also includes the portion of the Pescadero Creek Basin in Santa Cruz County.

Hydrographic Unit 10—San Francisco—This unit consists of the City and County of San Francisco.

CENTRAL COASTAL AREA

Hydrographic Unit 1—Santa Cruz—This unit consists of the drainage basins of streams tributary to the Pacific Ocean and Monterey Bay from the basin of Arroyo de los Frijoles in San Mateo County on the north to the northerly boundaries of the basins of Watsonville and Harkins Sloughs on the south.

Hydrographic Unit 2—San Benito—This unit consists of the drainage basins tributary to the Pajaro River above the U. S. Geological Survey gage near Chittenden, including those of the San Benito River, and Santa Anita, Pacheco, Llagas, and Uvas Creeks.

Hydrographic Unit 3—Pajaro—This unit consists of those lands draining to the Pajaro River between the gage near Chittenden and the mouth of the river, including the basins of Watsonville and Harkins Sloughs on the north and McClusky Slough on the south.

Hydrographic Unit 4—Upper Salinas—This unit includes the entire drainage basin of the Salinas River above the railroad station of Wunpost, as well as the foothill and mountainous portions downstream from Wunpost, lying above the contact between the erosion surfaces of the hills, and the terrace, bench, and valley fill depositional areas, with the exception of the drainage basin of Toro Creek near Spreckels.

Hydrographic Unit 5—Lower Salinas—This unit includes the floor of the Salinas River Valley downstream from Wunpost, lying below the contact between the erosion surfaces of the hills, and the terrace, bench, and valley fill depositional areas, the drainage basins of Toro Creek, a tributary of Salinas River near Spreckels, and of Elkhorn Slough north of the Salinas River, and lands directly tributary to Monterey Bay from the Salinas River south to the northerly boundary of the Canyon Del Rey group at Fort Ord.

Hydrographic Unit 6—Carmel—This unit consists of the drainage basins of the Carmel River and the Canyon Del Rey stream group. The streams of the latter group enter Monterey Bay and the Pacific Ocean between Fort Ord and the Carmel River.

Hydrographic Unit 7—Monterey Coast—This unit consists of the drainage basins of streams tributary to Carmel Bay and the Pacific Ocean south of the Carmel River Basin, from San Jose Creek on the north to an unnamed creek just north of Estero Point, on the south.

Hydrographic Unit 8—San Luis Obispo—This unit consists of drainage basins tributary to the Pacific Ocean from the basins of Ellysly and Villa Creeks on the north to that of Black Lake Canyon on the south.

Hydrographic Unit 9—Carrizo Plain—This unit consists of drainage basins of streams in southeastern San Luis Obispo County tributary to Soda Lake, usually a dry lake bed, with no outlet to the sea.

Hydrographic Unit 10—Santa Maria—This unit consists of the drainage basin of the Santa Maria River and of its major tributaries, the Cuyama and the Sisquoc Rivers, as well as the basin of Oso Flaco Creek which is tributary to a dune-locked lake somewhat north of the mouth of the Santa Maria River.

Hydrographic Unit 11—Santa Ynez—This unit consists of the drainage basins of the Santa Ynez River and San Antonio Creek, as well as those of certain minor streams directly tributary to the Pacific Ocean between the Santa Maria and Santa Ynez Rivers, from an unnamed creek entering the ocean at Mussel Rock to Canyon Tortuga.

Hydrographic Unit 12—Santa Barbara—This unit consists of the drainage basins of streams directly tributary to the Pacific Ocean and the Santa Barbara Channel from the basin of Bear Creek at Weser Spur to the southeastern boundary of the Rincon Creek Basin.

SOUTH COASTAL AREA

Hydrographic Unit 1—Ventura—This unit consists of the drainage basin of the Ventura River, as well as those of smaller streams directly tributary to the Pacific Ocean between Rincon Point (but not including the basin of Rincon Creek) and the easterly drainage boundary of Hall Canyon. The unit includes all of the City of Ventura.

Hydrographic Unit 2—Santa Clara-Calleguas—This unit consists of the drainage basins of the Santa Clara River and Calleguas Creek and their tributaries, as well as the Oxnard Plain lying between those streams, but draining directly to the Pacific Ocean. The upper part of the Santa Clara River Basin extends into Los Angeles County, and includes the Newhall-Saugus area.

Hydrographic Unit 3—Malibu—This unit consists of the drainage basins of streams in Ventura and Los Angeles Counties directly tributary to the Pacific Ocean, between Point Mugu and Topanga Beach, from La Jolla Canyon to Tuna Canyon.

Hydrographic Unit 4—San Gabriel Mountains—This unit consists of those portions of the drainage basins of the San Gabriel River and its tributaries, and of tributaries of the Los Angeles River, lying within the Angeles National Forest. There is an exception where the City of Los Angeles overlaps the national forest. In this area the city boundary is the southerly limit of the unit.

Hydrographic Unit 5—Upper Santa Ana—This unit includes the drainage basins of the Santa Ana River and its tributaries (including the San Jacinto River) above the Santa Ana Narrows at the Riverside-Orange county line. In addition, certain areas in eastern Los Angeles County are included, whose surface drainage is tributary to the San Gabriel River, but whose ground water basins are more intimately connected with the Santa Ana River Basin. These areas have been identified in the South Coastal Basin Investigation of the Division of Water Resources as the Claremont Heights, Live Oak, Pomona, and Spadra Basins.

Hydrographic Unit 6—Los Angeles—This unit consists essentially of the City of Los Angeles and neighboring cities and county areas from Santa Monica to Newport Beach, inclusive. It includes the portions of the drainage basins of the Los Angeles and San Gabriel Rivers and their tributaries lying south of the Angeles National Forest boundary except where the City of Los Angeles overlaps the national forest. In this area, the limit of the unit is the northerly boundary of the city. In addition, the unit includes the drainage basin of the Santa Ana River downstream from the Santa Ana Narrows, as well as areas directly tributary to the Pacific Ocean from the drainage basin of Topanga Canyon to Pelican Point two miles south of the entrance to Newport Bay. It does not include the Claremont Heights, Live Oak, Pomona, and Spadra Basins.

Hydrographic Unit 7—San Juan Capistrano—This unit consists of areas directly tributary to the Pacific Ocean from Pelican Point to, but not including, the drainage basin of the Santa Margarita River, including basins from Los Trancos Canyon on the north to Cockleburr Canyon on the south.

Hydrographic Unit 8—Santa Margarita-San Luis Rey—This unit consists of the drainage basins of the Santa Margarita and San Luis Rey Rivers and their tributaries, with the exception that the southerly boundary was drawn so as to exclude the Vista Irrigation District and to include the service area of the Carlsbad Mutual Water Company.

Hydrographic Unit 9—San Dieguito-Cottonwood—This unit consists of the drainage basin of Agua Hedionda Creek and the portions of the drainage basins of all streams in southern San Diego County tributary to the Pacific Ocean, from San Marcos Creek to the Tia Juana River, inclusive, east of the boundary of the San Diego Metropolitan Area. This boundary is delineated on sheets 7 and 8 of Plate 11. The northerly boundary of the unit is extended to include all of the Vista Irrigation District.

Hydrographic Unit 10—San Diego—This unit consists of the City of San Diego and neighboring cities and suburbs, as well as other nearby areas expected to be occupied by future expansion of the urban development centering on San Diego. The boundary of the unit was drawn on a series of rancho, township, section, and connecting lines so as to include the service areas of the San Dieguito and Santa Fe Irrigation Districts; most of El Cajon Valley; all of the gently rolling land east of San Diego, National City, and Chula Vista; and the Otay Mesa, east of San Ysidro. This boundary is delineated on sheets 7 and 8 of Plate 11.

CENTRAL VALLEY AREA

Hydrographic Unit 1—Goose Lake—This unit consists of the lands in California draining to Goose Lake. This drainage basin is tributary to the Pit River only in the case of an extremely wet series of years.

Hydrographic Unit 2—Pit River—This unit consists of the Pit River drainage basin to the junction of the Sacramento River, with the exception of the Goose Lake and McCloud River drainage basins.

Hydrographic Unit 3—McCloud River—This unit consists of the entire McCloud River drainage basin above the mouth of the river.

Hydrographic Unit 4—Sacramento River above Shasta Dam—This unit consists of the drainage basin of the main Sacramento River upstream from Shasta Dam, and exclusive of the Pit and McCloud River drainage basins.

Hydrographic Unit 5—West Side, Shasta Dam to Cottonwood Creek—This unit consists of the drainage basins of the tributaries entering the Sacramento River from the west between Shasta Dam and the U. S. Geological Survey gage near Red Bluff, excluding the City of Redding and the Anderson-Cottonwood Irrigation District.

Hydrographic Unit 6—East Side, Cow Creek to Paynes Creek—This unit consists of the drainage basins of those streams entering the Sacramento River from the east between Shasta Dam and the U. S. Geological Survey gage near Red Bluff, with the exception of a minor area in the Anderson-Cottonwood Irrigation District.

Hydrographic Unit 7—Red Bluff to Thomes Creek—This unit consists of the foothill and mountainous portions of drainage basins of streams from Dibble Creek to Moore Creek, inclusive, the latter a minor stream draining the base of the western foothills and entering the Sacramento River next upstream from Stony Creek. The easterly boundary of this unit is longitude 121° 15′ west.

Hydrographic Unit 8—Antelope Creek to Mud Creek—This unit consists of the mountainous and foothill portions of drainage basins tributary to the Sacramento River from the east, from Salt Creek to Mud Creek. The westerly boundary is approximately at the 300-foot contour.

Hydrographic Unit 9—Stony Creek—This unit includes all of the Stony Creek drainage basin above the Black Butte dam site, as well as the foothill portions of drainage basins south to the drainage boundary between Hunters Creek and Funks Creek. The easterly limit follows the line between Ranges 3 and 4 West to the line between Townships 20 and 21 North, thence along a series of section lines one and two miles west of the foregoing range line to the Glenn-Colusa county line.

Hydrographic Unit 10—Butte and Chico Creeks—This unit includes the mountainous and foothill portions of the drainage basins of Butte and Chico Creeks, as well as those of minor streams from Little Chico Creek to and including Ash Creek in Butte County. The easterly limit of the unit was drawn so as to follow the southern and eastern boundaries of the Paradise Irrigation District, thus placing all of the district in the unit. From north to south, the westerly limit of this unit follows section lines, longitude 121° 45′ west, the Chico-Oroville Road, and a line approximately following the Magalia Road.

Hydrographic Unit 11—Cortina Creek—This unit consists of the upstream portions of stream basins of the western foothills south from Funks Creek to, but not including, Cache Creek. The easterly limit of this unit was drawn to exclude the presently irrigated land on the floor of the Sacramento Valley. This line lies to the west of Highway 99W at a distance varying from less than one to more than six miles.

Hydrographic Unit 12—Feather River—This unit includes the entire drainage basin of the Feather River to and including Oroville (except that portion in the Paradise Irrigation District) as well as portions of the lower foothills directly tributary to the Sacramento Valley floor from the basin of Clear Creek (Butte County) to that of Schirmer Ravine, and an area including the Oroville-Wyandotte Irrigation District. The westerly limit of this unit follows the eastern and southern boundaries of the Paradise Irrigation District, the westerly boundary of the Clear Creek drainage basin, and the Lower Miocene Canal from the Coal Canyon Power House to the vicinity of Oroville. South of Oroville, this limit follows the Feather River and the line of a possible canal diverting from the river at an elevation of 125 feet. The southerly limit through the foothills coincides with the Butte-Yuba county line along Honcut Creek.

Hydrographic Unit 13—Yuba and Bear Rivers—This unit includes the entire drainage basins of the Yuba River above Englebright Dam and the Bear River above the Camp Far West Dam, as well as foothill areas directly tributary to the valley floor. Between the Yuba and Bear Rivers the westerly limit of this unit coincides with a possible canal line diverting from the Yuba River at an approximate elevation of 500 feet. South of the Bear River, the limit of this unit coincides with the westerly boundary of the Nevada Irrigation District. In the foothills, the southerly limit of Hydrographic Unit 13 coincides with the southerly boundary of the Auburn Ravine drainage basin. The northerly limit of the unit through the foothills follows the Yuba-Butte county line along Honcut Creek.

Hydrographic Unit 14—Cache Creek—This unit includes the Cache Creek drainage basin above the point of diversion of the Capay Valley Ditch near Rumsey, as well as the mountain and foothill portions of minor stream drainage between the Cache and Putah Creek Basins lying above the service area of the Winters Ditch of the Clear Lake Water Company.

Hydrographic Unit 15—American River—This unit includes the drainage basin of the American River above Folsom Dam, as well as the Placer County portion of the foothill area directly tributary to the Sacramento Valley floor, above the service area of a possible Folsom North Canal diverting from the American River at an elevation of approximately 200 feet and extending to the south boundary of the Auburn Ravine drainage basin.

Hydrographic Unit 16—Putah Creek—This unit includes the drainage basin of Putah Creek above the proposed diversion point of the Solano Project main canal, at an elevation of about 175 feet, as well as those portions of foothill and mountain areas lying above the service area of that projected canal, south to the boundary of the San Francisco Bay Area.

Hydrographic Unit 17—Anderson-Cottonwood—This unit consists essentially of the City of Redding and the Anderson-Cottonwood Irrigation District.

Hydrographic Unit 18—Tehama—This unit consists of that portion of the west side Sacramento Valley floor lying between longitude 121° 15′ west and the Sacramento River. The southern limit of the unit coincides with the Tehama-Glenn county line.

Hydrographic Unit 19—Vina—This unit consists of that portion of the east side Sacramento Valley floor lying between the approximate 300-foot contour and the Sacramento River. The southerly limit of this unit lies along the course of Big Chico Creek.

Hydrographic Unit 20—Orland—This unit consists of the service area of the Orland Project constructed by the U. S. Bureau of Reclamation, and the remainder of the Sacramento Valley floor in Glenn County lying west of the Glenn-Colusa Irrigation District. The westerly limit of this unit follows the line between Ranges 3 and 4 West, south to the line between Townships 20 and 21 North, thence along a series of section lines one and two miles west of the range line mentioned, to the Glenn-Colusa county line.

Hydrographic Unit 21—Chico—This unit consists of that portion of the east side Sacramento Valley floor lying between the foothills and the Sacramento River. The easterly limit follows section lines, longitude 121° 45′ west, the Chico-Oroville Road, and a line approximately following the Magalia Road. The southerly limit of the unit lies along the Butte-Glenn county line from the Sacramento River to a point about five miles east of the river, thence along a road running easterly to the community of Nelson, and another running northeasterly to a junction with the Magalia Road.

Hydrographic Unit 22—Arbuckle—This unit consists of portions of the west side Sacramento Valley floor lying between the westerly boundary of the Glenn-Colusa Irrigation District and the Colusa Trough on the east, and the foothills on the west. The westerly limit of this unit follows an irregular line from one and more than six miles west of Highway 99W. The southerly limit of this unit lies along Cache Creek Slough between Yolo and Knights Landing.

Hydrographic Unit 23—Colusa Trough—This unit consists of that portion of the Sacramento Valley floor on both sides of the Sacramento River, from the point of diversion of the Central Irrigation Canal to the confluence of the Sacramento and Feather Rivers, whose main source of irrigation water is the Sacramento River itself. The westerly limit of this hydrographic unit coincides with the westerly boundary of the Glenn-Colusa Irrigation District to a point south of Williams, thence along the west line of lands served by water pumped from the Back Borrow Pit of the Colusa Trough, to Knights Landing, thence along the southwestern levee of the Knights Landing Ridge Cut to a point south of Grays Bend. The easterly limit lies somewhat east of Angel Slough from the Glenn-Butte county line to a point near the intersection of the Mt. Diablo Meridian with the line between Townships 18 and 19 North, thence along the Mt. Diablo Meridian to the channel of Butte Creek, along Butte Creek and Butte Slough to the east levee of the Sutter By-pass, and thence along that levee to Nelson Slough, near Nicolaus, where the line changes to the west levee of the by-pass.

Hydrographic Unit 24—Feather River to Butte Slough—This unit consists of that portion of the east side Sacramento Valley floor which receives the majority of its water supply from the Feather River between Oroville and Live Oak. The Sutter Buttes lie wholly within Unit 24. The northerly limit of this unit lies along the Butte-Glenn county line from the Sacramento River to a point about five miles east of the river, thence along a road running easterly to the community of Nelson, and another running northeasterly to the Magalia Road. The easterly limit follows a line approximately along Magalia Road, the lower Miocene Canal, the Feather River from Oroville to a possible canal diversion to the east at an elevation of 125 feet, thence along this possible canal, the Butte-Yuba county line westerly along Honcut Creek, and the Sutter-Yuba county line along Feather River. The southerly limit coincides with the base of the foothills to the south of Sutter Buttes, with the west and east intercepting canals north of Sutter City, and with an extension of the line of these canals east to the Feather River. The westerly limit lies along the Mt. Diablo Meridian south to the channel of Butte Creek, and along Butte Creek and Butte Slough to the southerly limit.

Hydrographic Unit 25—Yuba—This unit consists of that portion of the east side Sacramento Valley floor lying between Sutter By-pass and the Feather River. This unit receives its major water supply from ground water. The northerly limit of this unit lies along the base of the foothills south of Sutter Buttes, along the west and east intercepting canals north of Sutter City, and along an extension of the line of these canals to the Feather River. The easterly limit is the Feather River and the westerly limit is the Sutter By-pass.

Hydrographic Unit 26—Marysville-Sheridan—This unit consists of that portion of the east side Sacramento Valley floor lying between the Feather River and the base of the eastern foothills. The northerly limit is Honcut Creek. The southern limit is a line two miles south of the line between Townships 12 and 13 North. The northern part of the easterly limit consists of the southerly part of a possible canal line diverting from the Feather River at an elevation of 125 feet. The central part is the line of a possible canal from the Yuba River diverting at an elevation of approximately 500 feet. The southern part of the easterly limit coincides with the westerly boundary of the Nevada Irrigation District. The westerly limit of this unit is the Feather River.

Hydrographic Unit 27—Woodland—This unit includes that portion of the west side Sacramento Valley floor, as well as the Capay Valley, receiving irrigation water from Cache Creek as well as from ground water. The easterly limit of this unit is the westerly boundary of Reclamation District 2035 and the west levee of Yolo By-pass. The southerly limit coincides with the Yolo-Solano county line along Putah Creek. The westerly limit is the limits of the service areas of the Clear Lake Water Company canals and of the Capay Valley Ditch. The northerly limit of the unit follows the northeasterly boundary of Rancho Cañada de Capay, the foothill line above Hungry Hollow, Cache Creek, and Cache Creek Slough to Knights Landing.

Hydrographic Unit 28—Carmichael—This unit includes that portion of the east side Sacramento Valley floor lying within the probable service area of the possible Folsom North and Folsom South Canals, the City of Sacramento, and that portion of Sacramento County lying above the Folsom North Canal. The northern limit is a line two miles south of the line between Townships 12 and 13 North. The westerly limit follows the easterly boundaries of Reclamation Districts 1001 and 1000 from the northwest corner of the unit to the American River, and along the American and Sacramento Rivers north and west of the City of Sacramento. South of the city it conforms to the easterly limit of the Sacramento-San Joaquin Delta as outlined in the "Report of Sacramento-San Joaquin Water Supervision for 1948," issued by the Division of Water Resources. The eastern part of the southerly limit of this unit is the northerly boundary of the Cosumnes Rancho. West of Highway 99 the limit follows an irregular line to the northeast corner of Reclamation District 1002. In Placer County the easterly limit of the unit follows the line of a possible Folsom North Canal at an elevation of approximately 200 feet. In Sacramento County, it follows the northerly and easterly county boundaries north of the American River, and, south of the river, the line of the proposed Folsom South Canal at an elevation of approximately 100 feet.

Hydrographic Unit 29—Dixon—This unit consists of that portion of the service area of the Solano Project lying in the Sacramento River Basin. The easterly limit of this unit coincides with the west levee of the Yolo By-pass, the westerly boundary of Reclamation District 2068, the westerly limit of the Sacramento-San Joaquin Delta as outlined in the "Report of Sacramento-San Joaquin Water Supervision for 1948," and a line through the northeastern corner of the Montezuma Hills. The southerly limit is the Sacramento River between Rio Vista and Collinsville. The westerly limit consists of the easterly limit of the San Francisco Bay Area and the westerly limit of the service area of the Solano Project main canal at an elevation of approximately 175 feet. The northerly limit consists of Putah Creek from Winters to the northeast corner of the Yolo-Solano county line, thence along a line east to the west levee of the Yolo By-pass.

Hydrographic Unit 30—Yolo—This unit consists of that portion of the Sacramento Valley floor, from Nicolaus to a point 11 miles south of Dixon, which area obtains its water supply from the lower Feather River, from the Sacramento River between Grays Bend and Sacramento, and from return flow in the Yolo By-pass. Reclamation District 2068, which constitutes the southernmost part of this unit, obtains its irrigation supply from Haas Slough, a tributary of Cache Slough.

The northern part of the easterly limit of this unit consists of the easterly boundaries of Reclamation Districts 1001 and 1000. Below the City of Sacramento the easterly limit of Unit 30 conforms to the westerly limit of the Sacramento-San Joaquin Delta as outlined in the "Report of Sacramento-San Joaquin Water Supervision for 1948.'' The westerly limit of this unit follows the westerly limit of the Sutter By-pass, the westerly boundary of Reclamation District 2035, the west levee of the Yolo By-pass, the westerly boundary of Reclamation District 2068, and thence by an irregular line to the southern limit 11 miles south of Dixon.

Hydrographic Unit 31—West Side, Kern County—This unit consists of the mountainous and foothill portions of the San Joaquin Valley slope of the Coast Range in San Luis Obispo, Kern, and Kings Counties. The easterly limit of this unit is, in general, the western edges of the alluvial fills of the Kettleman and Antelope Plains. The northerly limit lies along the Kings-Fresno county line and the northerly drainage boundary of Avenal Creek. The southerly limit is a line between the drainage basins of Sandy and Bitterwater Creeks near Taft.

Hydrographic Unit 32—Kern River and Tehachapi Mountains—This unit includes the mountainous and foothill portions of the named regions, as well as the Greenhorn Mountains and minor portions of the valley floor from the Kern-Tulare county line to a point near Maricopa. In addition to the drainage boundary of the upper Kern River, the northerly limit of the unit lies along the south boundary of the White River drainage basin. From the Tulare-Kern county line to the vicinity of Bakersfield, the westerly limit follows a series of section lines representing a division between lands presently irrigated and those not irrigated, from a point 11 miles east of Delano to a point 2 miles east of Bakersfield. From Bakersfield south the limit coincides with the northerly, easterly, and southerly boundaries of the Arvin-Edison Water Storage District. From the southwest corner of that district, the limit follows a series of section lines roughly corresponding to the southern limit of present irrigation development, from 1 to $2\frac{1}{2}$ miles south of Highway 33 to a point $1\frac{1}{2}$ miles southwest of Maricopa. The westerly limit is a line between the drainage basins of Sandy and Bitterwater Creeks.

Hydrographic Unit 33—Tule River—This unit consists of the mountainous and foothill portions of drainage basins of streams from the Tule River to White River, inclusive. The westerly limit follows a series of section lines from a point four miles east of Strathmore to a point five miles east of Richgrove, excluding all of the presently irrigated area on the San Joaquin Valley floor from this unit. Surprise and Pleasant Valleys, just east of Porterville, in this unit, are irrigated by ditches diverting water from both the north and south forks of the Tule River.

Hydrographic Unit 34—Kaweah River—This unit consists of the mountainous and foothill portions of the Kaweah River drainage basin and of minor stream basins from Lewis Creek to Sand Creek near Orange Cove. The westerly limit of this unit follows the easterly boundaries of the irrigation districts along the eastern edge of the valley floor, from Hills Valley and Orange Cove Irrigation Districts on the north to the Lindmore Irrigation District on the south.

Hydrographic Unit 35—Kings River—This unit includes the mountainous and foothill portions of the Kings River drainage basin above the point of diversion of the Alta Canal, as well as those of minor stream basins from Dry Creek near Clovis on the north to Wahtoke Creek on the south. Between the northwesterly corner of the unit and the Kings River, the westerly limit of this unit follows the Friant-Kern Canal, while south of the river it coincides with the easterly boundary of the Alta Irrigation District and the northerly boundary of the Orange Cove Irrigation District.

Hydrographic Unit 36—Antelope Plain—This unit consists of the western portion of the valley floor tributary to Tulare Lake, which obtains irrigation supplies from ground water basins replenished by the streams of Hydrographic Unit 31, immediately to the west. Contained within this unit are the Kettleman Hills and the Buena Vista Hills. The westerly limit of this unit is, in general, the westerly edges of the alluvial fills of the Kettleman and Antelope Plains. The northerly limit is the Fresno-Kings county line and the line between Townships 20 and 21 South. The northern portion of the easterly limit coincides with the westerly boundary of the Tulare Lake Basin Water Storage District, the central portion with the westerly boundary of the Buena Vista Water Storage District, and the southern portion, in the neighborhood of Taft, with the westerly limit of certain lands irrigated directly from Buena Vista Lake.

Hydrographic Unit 37—Kern—This unit consists of those lands receiving water directly or indirectly from the Kern River. The northerly limit of this unit coincides with, from east to west, the Tulare-Kern county line (except for that portion of the Delano-Earlimart Irrigation District in Kern County), the northerly boundary of the Alpaugh Irrigation District, and the southerly boundary of the main portion of the Tulare Lake Basin Water Storage District. However, a minor detached portion of this water storage district lies within Hydrographic Unit 37. The westerly limit of the unit consists of, from north to south, the westerly boundary of the Buena Vista Water Storage District and the westerly limit of certain lands irrigated directly from the Buena Vista Lake. The southerly limit extends from a point $1\frac{1}{2}$ miles southwest of Maricopa along a series of section lines from 1 to $2\frac{1}{2}$ miles south of Highway 33, and along the southerly boundary of the Arvin-Edison Water Storage District. The easterly limit coincides with the easterly and northerly boundaries of that district, from a point near Wheeler Ridge to a point two miles east of Bakersfield. North of the latter point, the limit follows a series of section lines to the Kern-Tulare county line at a point 11 miles east of Delano.

Hydrographic Unit 38—Earlimart—This unit consists of those lands receiving water supplies either from Tule River and other streams of Hydrographic Unit 33 to the east, or from ground water. The southerly limit of this unit is the Tulare-Kern county line and the southerly boundary of the Delano-Earlimart Irrigation District in Kern County. The westerly limit is, from south to north, the line between Ranges 23 and 24 East, the eastern and northerly boundaries of the Alpaugh Irrigation District, the southeast corner of the Tulare Lake Basin Water Storage District, and the Tulare-Kings county line. The northerly limit is drawn to place the Lower Tule River and Porterville Irrigation Districts in this unit. The easterly limit follows a series of section lines from a point four miles east of Strathmore to a point five miles east of Richgrove, placing the presently irrigated area on this portion of the San Joaquin Valley floor in this unit.

Hydrographic Unit 39—Visalia—This unit consists of those lands receiving the major portion of their water supply from the Kaweah River, or from ground water replenished by the Kaweah or other streams of Hydrographic Unit 34, directly to the east. The southerly limit of this unit is a line drawn to exclude the Corcoran Irrigation District, and to include the service area of the Elk Bayou Ditch Company, as well as the Tulare, Lindmore, and Lindsay-Strathmore Irrigation Districts, in this unit.

The easterly limit of this unit corresponds to the easterly boundaries of a line of irrigation districts from Lindsay-Strathmore on the south to Hills Valley and Orange Cove on the north. The northerly and westerly limits of the unit consist of the easterly and southerly boundaries of the Alta Irrigation District, and of a line drawn so as to include the service area of the Lakeside Ditch Company in this unit.

Hydrographic Unit 40 — Fresno-Hanford — This unit consists of that portion of the valley floor which receives the majority of its water supply from the Kings River, and corresponds generally to the service area of members of the Kings River Water Association, excluding the area immediately surrounding Tulare Lake. Between Friant and the Kings River, the easterly limit of Unit 40 follows the Friant-Kern Canal. South of the Kings River the limit follows the easterly and southerly boundaries of the Alta Irrigation District, and a line drawn to include the Peoples Ditch service area and to exclude the service area of the Lakeside Ditch Company. The northerly limit of Unit 40 coincides with the northerly boundary of the Fresno Irrigation District, the course of the San Joaquin River, and the southerly boundary of the Mowry Ranch lying south of the San Joaquin River near Mendota. The westerly limit of the unit follows Fresno Slough and the westerly limit of the service area of members of the Kings River Water Association. The southern limit is the line between Townships 20 and 21 South.

Hydrographic Unit 41—Tulare Lake—This unit consists of the Tulare Lake bed and areas immediately surrounding the lake. The northerly limit of the unit consists of the line between Townships 20 and 21 South and a line drawn to include the Corcoran Irrigation District. The eastern limit coincides with the Kings-Tulare county line. The southerly and westerly limits coincide with the southerly and westerly boundaries of the main portion of the Tulare Lake Basin Water Storage District.

Hydrographic Unit 42—Mount Diablo—This unit consists of the mountainous and foothill portions of the Coast Range above the San Joaquin Valley floor, from the westerly drainage boundary of Markley Canyon to the northerly boundary of the Mountainhouse Creek drainage basin. The northern limit of the unit is a line one mile north of the line between Townships 1 and 2 North. The easterly limit coincides with the westerly boundaries of the East Contra Costa and Byron-Bethany Irrigation Districts.

Hydrographic Unit 43—Altamont to San Luis Creek—This unit consists of the mountainous and foothill portions of the Coast Range tributary to the San Joaquin Valley, between the northerly drainage boundary of Mountainhouse Creek and the southerly drainage boundary of San Luis Creek. The easterly limit of this unit follows, in general, the edge of the San Joaquin Valley floor, except between Orestimba and Garzas Creeks, where it coincides with part of the westerly boundary of the Orestimba Water District.

Hydrographic Unit 44—West Side, Los Banos Creek to Avenal—This unit consists of the mountainous and foothill portions of the Coast Range tributary to the San Joaquin Valley, from the northerly drainage boundary of Los Banos Creek to the northerly drainage boundary of Avenal Creek. The easterly limit of this unit follows, in general, the edge of the San Joaquin Valley floor. However, the bench land region above the valley floor through which flow Los Banos, Salt, and Ortigalita Creeks, is excluded from the unit.

Hydrographic Unit 45—San Joaquin River—This unit includes the drainage basin of the San Joaquin River above Friant Dam, as well as a minor part of the foothill area tributary to the San Joaquin River just downstream from Friant Dam and lying above the Friant-Kern and Madera Canals. The most important stream draining this latter area is Little Dry Creek, which enters the San Joaquin River from the east.

Hydrographic Unit 46—Chowchilla-Fresno Rivers—This unit includes the mountainous and foothill portions of the drainage basins of the Fresno and Chowchilla Rivers above the crossings of the Madera Canal, as well as the drainage basins of intermediate minor streams from Little Dry Creek tributary to the valley floor near Madera, on the south, to the unnamed stream next south of Dutchman Creek, on the north. From Friant to the Chowchilla River, the westerly limit of this unit follows the Madera Canal. North of the Chowchilla River, the limit follows the line of a possible canal diverting from the Merced River at an elevation of approximately 400 feet.

Hydrographic Unit 47—Merced River—This unit includes the mountainous and foothill portions of the Merced River drainage basin, basins of minor east side streams from Dutchman Creek to the Mariposa-Tuolumne and Merced-Stanislaus county lines. The westerly limit of this unit south of the Merced River lies along the line of a possible canal diverting from the Merced River at an elevation of approximately 400 feet. North of the Merced River the westerly limit corresponds to a canal line diverting from the Tuolumne River at an elevation of about 300 feet.

Hydrographic Unit 48—Tuolumne River—This unit consists of the mountainous and foothill portions of the drainage basin of the Tuolumne River above La Grange Dam, together with similar portions of minor drainage basins between the Mariposa-Tuolumne and Merced-Stanislaus county lines, and the Tuolumne River. The westerly limit of this unit follows the line of a possible canal diverting from the Tuolumne River at an elevation of approximately 300 feet.

Hydrographic Unit 49—Stanislaus River—This unit includes mountainous and foothill portions of the drainage basin of the Stanislaus River above Goodwin Dam, as well as similar portions of the Dry Creek (Modesto) drainage basin. The westerly limit of this unit follows the line of a possible canal diverting from the Stanislaus River at an elevation of approximately 300 feet.

Hydrographic Unit 50—Mokelumne-Calaveras Rivers—This unit includes the mountainous and foothill portions of the Calaveras River drainage basin above Hogan Dam and the Mokelumne River drainage basin above Pardee Dam, as well as similar portions of the Littlejohns Creek and Bear Creek drainage basins. The westerly limit of this unit follows lines of possible canals diverting from the Calaveras River. The south canal line is at an approximate elevation of 300 feet, while the north canal line is at an elevation of approximately 550 feet.

Hydrographic Unit 51—Cosumnes River—This unit includes the mountainous and higher foothill portions of the Cosumnes River drainage basin, as well as similar portions of drainage basins of lesser streams from Jackson Creek on the south to Deer Creek (Sloughhouse) on the north. The westerly limit follows the lines of possible canals from the Nashville dam site on the Cosumnes River. The south canal line would divert from the Cosumnes River at an elevation of approximately 800 feet, with a secondary diversion from Dry Creek (Ione) at an approximate elevation of 400 feet. The north canal line would divert at an elevation of approximately 800 feet.

Hydrographic Unit 52—Antioch—This unit consists of that portion of the west side of the San Joaquin Valley floor which obtains its major water supply from channels of the Sacramento-San Joaquin Delta, excluding lands in the Delta itself. The westerly limit of this unit consists of the eastern limit of the San Francisco Bay Area, a line one mile north of the line between Townships 1 and 2 North, and the westerly boundaries of the East Contra Costa and Byron-Bethany Irrigation Districts. The northerly limit follows the main channel of the San Joaquin River passing Antioch, and the northerly boundary of the East Contra Costa Irrigation District. The easterly limit of the unit consists of the easterly boundary of this district, the sea level contour as it crosses the Byron Tract, Old River, and Tom Paine Slough. The southerly limit of the unit follows the northerly boundary of the Banta-Carbona Irrigation District, and the southerly boundary of the West Side Irrigation District.

Hydrographic Unit 53—Delta-Mendota—This unit consists of those lands of the west side San Joaquin Valley floor receiving the majority of their water supplies from ground water replenished by the streams of Hydrographic Unit 43, directly to the west, and from the Delta-Mendota Canal of the Central Valley Project. The westerly limit of this unit is, in general, the edge of the San Joaquin Valley floor, except between Orestimba and Garzas Creeks where it coincides with part of the westerly boundary of the Orestimba Water District. The northerly limit of the unit consists of the southerly boundary of the West Side Irrigation District. The easterly limit follows the westerly boundaries of the Banta-Carbona and the West Stanislaus Irrigation Districts, the easterly boundary of the Salado Water District and, in general, the westerly limit of the service area of the former San Joaquin Canal Company.

Hydrographic Unit 54—West Side, San Joaquin Valley—This unit consists of that portion of the west side San Joaquin Valley floor between Los Banos and Avenal, which obtains the majority of its water supply from streams of Hydrographic Unit 44, directly to the west, or from underground waters fed by percolation from these streams and by underflow from the east. The westerly limit of this unit is, in general, the edge of the San Joaquin Valley floor, except for a section through the bench-land region above the valley floor, through which flow Los Banos, Salt, and Ortigalita Creeks. The southerly limit consists of the Fresno-Kings county line and the line between Townships 20 and 21 south. The easterly limit follows the westerly limit of the service area of members of the Kings River Water Association, and Fresno Slough to its junction with the San Joaquin River at Mendota. The northerly limit of Unit 54 consists of the Delta-Mendota Canal and the southwesterly limit of the Firebaugh Canal Company service area.

Hydrographic Unit 55—Madera—This unit consists of that portion of the east side San Joaquin Valley floor whose major sources of water supply are the Madera Canal, the Fresno and Chowchilla Rivers and other streams of Hydrographic Unit 46, directly to the east, and ground water supplies replenished by these sources. The easterly limit of this unit is the Madera Canal. The southerly limit consists of the northerly boundary of the Fresno Irrigation District and the channel of the San Joaquin River. The westerly limit of the unit follows the easterly limit of the service area of the Columbia Canal Company and the San Joaquin River. The northerly limit of the unit consists of the Merced-Madera county line along the Chowchilla River, and the line between Townships 9 and 10 South.

Hydrographic Unit 56—Merced—This unit consists of that portion of the east side San Joaquin Valley floor whose major sources of water supply are the Merced River and other streams of Hydrographic Unit 47, directly to the east. The easterly boundary of this unit is the line of a possible canal diverting from the Merced River at an approximate elevation of 400 feet. The southerly limit of this unit consists of the Merced-Madera county line along the Chowchilla River and the line between Townships 9 and 10 South. The westerly limit is the San Joaquin River. The northerly limit follows Dry Creek (Snelling) and the Merced River.

Hydrographic Unit 57—Los Banos—This unit consists of that portion of the San Joaquin Valley floor obtaining the majority of its water supply from the San Joaquin River at the Mendota Pool, and by diversions from the left bank of the river between Mendota and Patterson. The easterly limit of this unit consists of the easterly limit of the Columbia Canal Company service area and the main stem of the San Joaquin River. The southerly limit coincides with the southerly boundary of the Mowry Ranch south of the San Joaquin River near Mendota. The westerly limit of the unit consists of the westerly limit of the Firebaugh Canal Company service area, the Delta-Mendota Canal, a generalized line representing the westerly limit of the service area of the former San Joaquin Canal Company, and the easterly boundary of the Salado Water District. The northerly limit of this unit coincides with the northerly boundary of the Central California Irrigation District near Crows Landing.

Hydrographic Unit 58—Modesto—This unit consists of that portion of the east side San Joaquin Valley floor receiving the major part of its water supply from the Tuolumne River. The easterly limit of this unit consists of possible canal lines diverting from the Tuolumne River at an elevation of approximately 300 feet. The southerly limit follows Dry Creek (Snelling) and the Merced River. The westerly limit of the unit is the San Joaquin River. The northerly limit consists of, from east to west, the line between Townships 2 and 3 South, Dry Creek (Modesto), the northerly boundary of the Modesto Irrigation District, and the Stanislaus River.

Hydrographic Unit 59—Vernalis—This unit consists of that portion of the west side San Joaquin Valley floor between Patterson and Tracy, whose major source of water supply is the San Joaquin River, with supplemental supply from the Delta-Mendota Canal. The easterly limit of this unit is the San Joaquin River. The southerly limit coincides with the northerly boundary of the Central California Irrigation District. The westerly limit of the unit consists of the westerly boundaries of the West Stanislaus and Banta-Carbona Irrigation Districts. The northerly limit coincides with the northerly boundary of the last named district.

Hydrographic Unit 60—Oakdale—This unit consists of that portion of the east side San Joaquin Valley floor whose major source of water supply is the Stanislaus River. The easterly limit of this unit follows the line of a possible canal diverting from the Stanislaus River at an elevation of approximately 300 feet. The southerly limit consists of, from east to west, the line between Townships 2 and 3 South, Dry Creek (Modesto), the northerly boundary of the Modesto Irrigation District, and the Stanislaus River. The westerly limit is the main channel of the San Joaquin River. The northerly limit of the unit consists of the northerly boundary of the drainage basin of Simmons Creek and the northerly boundary of the South San Joaquin Irrigation District.

Hydrographic Unit 61—Stockton—This unit consists of those portions of the east side San Joaquin Valley floor whose major sources of water supply are the Calaveras and Mokelumne Rivers, ground water supplies replenished by streams of Hydrographic Units 50 and 51, and the proposed Folsom South Canal. The southerly limit of this unit consists of the northerly boundaries of the Simmons Creek drainage basin and of the South San Joaquin Irrigation District. South of the Mokelumne River the easterly limit of the unit follows the lines of possible canals to divert from the Calaveras River. The south diversion would be at an approximate elevation of 300 feet, while the north diversion would be at an elevation of about 550 feet. North of the Mokelumne River the easterly limit is the proposed Folsom South Canal at an approximate elevation of 100 feet. The northerly limit of the unit consists of the northerly boundary of the Cosumnes Rancho and, west of U. S. Highway 99, an irregular line to the northeast corner of Reclamation District 1002. The westerly limit coincides with the easterly limit of the Sacramento-San Joaquin Delta as outlined in the "Report of Sacramento-San Joaquin Water Supervision for 1948," issued by the State Division of Water Resources.

Hydrographic Unit 62—Ione—This unit consists of those portions of the lower foothills of western Amador and El Dorado Counties, and eastern San Joaquin and Sacramento Counties, which are capable of being irrigated from canals delivering water developed at the Nashville dam site on the Cosumnes River. The easterly limit of the unit follows the possible lines of these canals. The south canal would divert at an elevation of approximately 800 feet, with a secondary diversion from Dry Creek (Ione) at an elevation of about 400 feet. The north diversion would be at an elevation of about 800 feet. The southerly limit of the unit is the Mokelumne River. The westerly limit follows the line of the proposed Folsom South Canal at an approximate elevation of 100 feet. The northerly limit is the southerly edge of Folsom Reservoir.

Hydrographic Unit 63—Sacramento-San Joaquin Delta—This unit consists of the area of the Delta as outlined in the "Report of Sacramento-San Joaquin Water Supervision for 1948," issued by the State Division of Water Resources. An exception is in an area immediately north and west of Rio Vista, where Hydrographic Unit 63 extends into the Montezuma Hills, thus including irrigable acreage along the northeastern base of the hills whose natural source of water supply is the Sacramento-San Joaquin Delta.

LAHONTAN AREA

Hydrographic Unit 1—Surprise Valley—This unit includes the California portions of drainage basins tributary to the Upper, Middle, and Lower Alkali Lakes, as well as the California portions of the Twelve Mile Creek and Duck Flat drainage basins, both of which drain into neighboring states.

Hydrographic Unit 2—Madeline Plains—This unit consists of the California portions of drainage basins tributary to the Madeline Plains.

Hydrographic Unit 3—Honey Lake—This unit includes the drainage basins of the Susan River and other streams tributary to Honey Lake, as well as the basins of Pine Creek and other streams tributary to Eagle Lake. In addition, this unit includes the California portions of drainage basins of Smoke Creek and Rush Creek which flow into Nevada.

Hydrographic Unit 4—Truckee River—This unit consists of the California portion of the drainage basins of the Truckee River and its tributaries, including those portions of Lake Tahoe and its tributaries which lie within California.

Hydrographic Unit 5—Carson River—This unit consists of the California portions of the drainage basins of the East and West Forks of the Carson River and their tributaries.

Hydrographic Unit 6—Walker River—This unit consists of the California portions of the drainage basins of the East Walker and West Walker Rivers and their tributaries.

Hydrographic Unit 7—Mono Lake—This unit consists of the California portions of drainage basins tributary to Mono Lake.

Hydrographic Unit 8—Adobe Valley—This unit includes the drainage basin of Adobe Creek, southeast of Mono Lake, as well as the California portions of other minor basins tributary to Adobe Valley, including Black Canyon and the tributaries of Black Lake. In addition, this unit includes the California portion of the area tributary to Huntoon Valley in Nevada.

Hydrographic Unit 9—Owens River—This unit consists of the California portions of the drainage basins of the Owens River and its tributaries, as well as basins of other streams directly tributary to Owens Lake.

Hydrographic Unit 10—Death Valley—This unit consists of the California portion of the drainage basins of the Amargosa River, Salt Creek, and other tributaries of Death Valley, all of the California portions of basins draining the east side of the White Mountains, and many other enclosed basins between Owens Lake and the Mojave River. The most important of these enclosed basins are Eureka Valley, Saline Valley, Panamint Valley, Indian Wells Valley, and Searles Lake. The westerly limit of the unit consists of the crests of the White Mountains and the Inyo Mountains, the drainage boundary between Owens Lake and Haiwee Reservoir, and the summits of the Sierra Nevada and the Tehachapi Mountains to a point one mile east of Caliente Mountain. The southerly limit consists of the northerly drainage boundaries of basins tributary to Rosamond Lake, Rogers Lake, and the Mojave River, the crest of the Soda Mountains, a line through the Devil's Playground at Baker, the northerly drainage boundary of Halloran Wash, a line between Granite Spring and Cima, and the summit of the New York Mountains. The easterly limit is the California-Nevada state line.

Hydrographic Unit 11—Mojave River—This unit consists of the drainage basins of the Mojave River and other streams tributary to Soda Lake in the vicinity of Baker. In addition to the southerly, westerly, and northerly boundaries of the Mojave River drainage basin, the limit of the unit consists of the summit of the Soda Mountains, a line through the Devil's Playground at Baker, the northerly drainage boundary of Halloran Wash, a line between Granite Spring and Cima, and the northerly boundary of the Colorado Desert Area.

Hydrographic Unit 12—Antelope Valley—This unit consists of drainage basins tributary to Rosamond Lake, Rogers Lake, and Mirage Lake.

COLORADO DESERT AREA

Hydrographic Unit 1—Twentynine Palms—This unit consists of the major portion of the interior dissected drainage of the Colorado Desert, tributary to a number of dry lakes including Bristol Lake (with the exception of the long dry wash entering that lake from the northeast near Cadiz which is included in Hydrographic Unit 6). The more important of these lakes are Cadiz, Palen, Ford, Dale, Mesquite, Deadman, and Lucerne. The westerly and northerly limits of the unit are part of the easterly limit of the South Coastal Area and part of the southerly limit of the Lahontan Area. The easterly limit consists of the crests of the Marble Mountains, Ship Mountains, Old Woman Mountains, Iron Mountains, Granite Mountains, Little Maria Mountains, McCoy Mountains, and Mule Mountains, to the northwestern end of the Palo Verde Mountains. The southerly limit consists of a line through the summits of the Little Chuckawalla Mountains, Chuckawalla Mountains, Hexie Mountains, Orocopia Mountains, Eagle Mountains, and Little San Bernardino Mountains.

Hydrographic Unit 2—Coachella Valley—This unit includes the drainage basins of the Whitewater River and its tributaries, as well as other minor basins tributary to the Coachella Valley at the northwesterly end of the Salton Sea. These include Box Canyon Wash and an unnamed stream entering the Salton Sea one-half mile south of Mortmar, as well as Barton Canyon and an unnamed stream entering Salton Sea at Fish Springs.

Hydrographic Unit 3—Salton Sea—This unit includes all of the drainage basins directly tributary to the Salton Sea from the northeast and southwest, as well as those areas tributary to the Imperial Valley lying outside the Imperial Irrigation District. The northerly limit of the unit consists of the crest of the Santa Rosa Mountains, the northerly drainage boundary of a stream entering Salton Sea one mile east of Coolidge Springs, the northerly shore of Salton Sea, the northerly drainage boundary of a stream entering Salton Sea one-half mile east of Date Palm Beach, the crest of the Orocopia Mountains, the easterly drainage boundary of Salton Creek, the crest of the Chocolate Mountains, and a line drawn to meet the easterly boundary of the Imperial Irrigation District at a point eight miles south of Glamis. The southerly limit of this unit consists of the easterly, northerly, and westerly boundaries of the Imperial Irrigation District (except that north of Superstition Mountain the limit follows State Highway 78), and the southerly border of the State.

Hydrographic Unit 4—Imperial Valley—This unit includes the Imperial Irrigation District (with the exception of the district's Pilot Knob Unit), as well as certain other lands west of the Imperial Valley, including Superstition Mountain. The limits of the unit coincide with the boundaries of the irrigation district, with the exception of that portion north of Superstition Mountain, where the limit follows State Highway 78.

Hydrographic Unit 5—Colorado River—This unit includes the California portions of drainage basins tributary to the Colorado River (with the exception of that portion of the drainage basin of Piute Wash upstream from the narrowest portion of the gap between the Sacramento Mountains and the Dead Mountains), as well as tributaries of the Pilot Knob Mesa.

Hydrographic Unit 6—Lanfair Valley—This unit consists of the eastern portion of the interior dissected drainage basins of the Colorado Desert, including those of Lanfair Valley, tributaries of Danby Lake, the long dry wash tributary to Bristol Lake (in Hydrographic Unit 1), stretching from Goffs to Cadiz, Piute Wash upstream from the narrowest part of the gap between the Sacramento and the Dead Mountains, and other minor basins. The northerly limit of Hydrographic Unit 6 consists of the crest of the New York Mountains and the California-Nevada state line. The easterly limit consists of a line through the summits of the Dead Mountains, Center Hills, Turtle Mountains and Riverside Mountains. The southerly limit was drawn through the crests of the Big Maria Mountains, Little Maria Mountains, and Granite Mountains. The westerly limit follows a line through the crests of the Iron Mountains, Old Woman Mountains, Ship Mountains, Marble Mountains, Providence Mountains, and Mid Hills.

APPENDIX D

SOURCES AND DATES OF LAND USE SURVEY DATA

SOURCES AND DATES OF LAND USE SURVEY DATA

General area	Source of data	Approximate date of survey
North Coastal Area		
National Forest, outside Klamath River Drainage Basin	U. S. Forest Service	1948
Remainder of North Coastal Area	State Division of Water Resources	1948–53
San Francisco Bay Area		
Entire San Francisco Bay Area	State Division of Water Resources	1949
Central Coastal Area		
National Forest	U. S. Forest Service	1948
Upper Salinas Valley	U.S. Bureau of Reclamation	1948
Remainder of Central Coastal Area	State Division of Water Resources	1948–50
South Coastal Area		
National Forest	U. S. Forest Service	1948
Remainder of South Coastal Area	State Division of Water Resources	1948–49
Central Valley Area		
Sacramento River Basin		
National Forest	U. S. Forest Service	1948
Putah Creek Valley	U. S. Bureau of Reclamation	1947
Valley floor of the Sacramento Valley, excepting Sutter, Placer, and Yuba Counties, and Glenn-Colusa Irrigation District	U. S. Bureau of Reclamation	1946–50
Remainder of Sacramento River Basin	State Division of Water Resources	1948–50
San Joaquin River Basin		
National Forest	U. S. Forest Service	1948
Portions of the valley floor of the San Joaquin Valley	U. S. Bureau of Reclamation	1948
South San Joaquin Irrigation District	South San Joaquin Irrigation District	1948
Oakdale Irrigation District	Oakdale Irrigation District	1948
Modesto Irrigation District	Modesto Irrigation District	1948
Turlock Irrigation District	Turlock Irrigation District	1948
Waterford Irrigation District	Waterford Irrigation District	1948
Central Valley Area—Continued		
San Joaquin River Basin—Continued		
Merced Irrigation District	Merced Irrigation District	1948
West Side Irrigation District	West Side Irrigation District	1949
Byron-Bethany Irrigation District	Byron-Bethany Irrigation District	1949
East Contra-Costa Irrigation District	East Contra-Costa Irrigation District	1949
San Joaquin Canal Company	San Joaquin Canal Company	1948
Firebaugh Canal Company	Firebaugh Canal Company	1948
Columbia Canal Company	Columbia Canal Company	1948
San Luis Canal Company	San Luis Canal Company	1948
Remainder of the San Joaquin River Basin, including Delta	State Division of Water Resources	1947–50
Tulare Lake Basin		
Alta Irrigation District	Alta Irrigation District	1948
Kaweah and Tule River Delta	U. S. Bureau of Reclamation	1947–48
Kern County Land Company	Kern County Land Company	1950
West Side, San Joaquin Valley	U. S. Bureau of Reclamation	1950
Remainder of Tulare Lake Basin	State Division of Water Resources	1948–50
Lahontan Area		
National Forest	U. S. Forest Service	1948
Remainder of Lahontan Area	State Division of Water Resources	1950
Colorado Desert Area		
National Forest	U. S. Forest Service	1948
Imperial Valley	Imperial Irrigation District	1950
Reservation Division, Yuma Project	U. S. Bureau of Reclamation	1948
Remainder of Colorado Desert Area	State Division of Water Resources	1950

APPENDIX E

SOURCES OF LAND CLASSIFICATION SURVEY DATA

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SOURCES OF LAND CLASSIFICATION SURVEY DATA

NORTH COASTAL AREA

The lands of the Russian River drainage area, and of the Lower Eel River area around Eureka and Fortuna were classified according to the Index Rating of Soils developed by R. Earl Storie of the University of California. The index was applied to soil surveys made cooperatively by the United States Department of Agriculture and the University of California. Slight modifications of the ratings were made by the Division of Water Resources by projection of data on topographic quadrangles, and elimination of areas with excessively rough topography. The accuracy of the classification is considered to be fair.

Lands of the Klamath River drainage basin were classified by the Division of Water Resources on aerial photographs to a scale of 1/20,000. The accuracy of the classification is considered to be good.

Lands of the coastal area, except for the lower Eel River area and the Klamath River Basin, were classified by the Division of Water Resources on topographic quadrangles to a scale of 1/62,500. The accuracy of the classification is considered to be fair to good.

Lands of the remainder of the North Coastal Area were classified by the Division of Water Resources on topographic quadrangles to a scale of 1/125,000. The accuracy of the classification is considered to be fair.

SAN FRANCISCO BAY AREA

All lands were classified by the Division of Water Resources as to their suitability for urban use. The accuracy of the classification is considered to be good.

CENTRAL COASTAL AREA

Lands of the Pajaro Valley were classified by the Division of Water Resources on aerial photographs to a scale of 1/20,000. The accuracy of the classification is considered to be good.

Lands of the Carrizo Plain and the Cuyama Valley were classified by the Division of Water Resources on topographic quadrangles to a scale of 1/62,500. The accuracy of the classification is considered to be good to fair.

The United States Bureau of Reclamation land classification was used for the Santa Barbara area. The accuracy of the classification is considered to be good.

Lands of the remainder of the Central Coastal Area were classified according to the Storie Index Rating of Soils, as mapped in various soil surveys. The data were modified by the Division of Water Resources by projection on topographic quadrangles, with elimination of areas of excessively rough topography. The accuracy of the classification is considered to be fair.

SOUTH COASTAL AREA

Lands of Ventura County and the Santa Margarita River drainage area were classified by the Division of Water Resources on aerial photographs to a scale of 1/20,000. The accuracy of the classification is considered to be good.

In those other portions of the South Coastal Area where soil survey data were not available, the irrigable lands were delineated by the Division of Water Resources on topographic quadrangles to a scale of 1/62,500. The accuracy of the classification is considered to be good to fair.

In the remainder of the area, the classification of lands was made by the University of California by applying the Storie Index Ratings of Soils to the various soil surveys which had been made cooperatively by the United States Department of Agriculture and the University of California. The data were modified to some extent by a Division of Water Resources field check. The over-all accuracy of the classification is considered to be fair.

CENTRAL VALLEY AREA

For the Sacramento Valley floor area, the land classification data were obtained from the United States Bureau of Reclamation. A field check of the nonirrigable lands was made by the Division of Water Resources. Accuracy of the classification is considered to be good.

For the San Joaquin Valley floor area the land classification data were obtained from the United States Bureau of Agricultural Economics. A field check of the nonirrigable lands was made by the Division of Water Resources. Accuracy of the classification is considered to be good.

The foothill lands of the counties of the Mother Lode region, from Butte on the north to Mariposa on the south, and all the Upper Feather River drainage area were classified by the Division of Water Resources on aerial photographs to a scale of 1/20,000. The accuracy of the classification is considered to be good.

Lands of the Delta area were classified from soil survey data of the University of California and United States Department of Agriculture. The accuracy of the classification is considered to be good.

Lands of the Alturas and Big Valley areas were classified on the basis of the Storie Index Rating of

Soils, as mapped in soil surveys, with slight field modification. The accuracy of the classification is considered to be fair.

Lands of the San Joaquin Valley foothill and mountain areas and those of the Sacramento Valley west side foothills were classified by the Division of Water Resources on topographic quadrangles to a scale of 1/62,500. The accuracy of the classification is considered to be good to fair.

Lands of the remainder of the Central Valley Area were classified by the Division of Water Resources on topographic quadrangles and United States Forest Service maps to a scale of 1/125,000. The accuracy of the classification is considered to be fair.

LAHONTAN AREA

Lands of the Honey Lake and Surprise Valley areas were classified by the University of California by applying the Storie Index Ratings of Soils to the various soil surveys which had been made cooperatively by the United States Department of Agriculture and the University of California. These data were modified to some extent by the Division of Water Resources. The accuracy of the classification is considered to be fair.

Lands of the remainder of the Lahontan Area were classified by the Division of Water Resources on topographic maps to a scale of 1/125,000. The accuracy of the classification is considerd to be fair.

COLORADO DESERT AREA

Lands of the Colorado Desert Area, except for those lands having rights in and to the waters of the Colorado River, were classified by the Division of Water Resources on maps to a scale of 1/125,000. The accuracy of the classification is considered to be fair.

APPENDIX F

WATER REQUIREMENTS FOR FISH AND WILDLIFE IN CALIFORNIA

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TABLES

WATER REQUIREMENTS FOR FISH AND WILDLIFE IN CALIFORNIA

INTRODUCTION

The Division of Water Resources, in the course of the investigation leading to publication of this bulletin, requested that the California Department of Fish and Game prepare a series of estimates of the minimum flows of water required to protect and maintain the fish life in major streams of the State. These streams were divided by the Division into four classes, according to anticipated degree of water development for various purposes that would compete with recreational or commercial fishing requirements for water. The description of these classes is included in the attached explanatory communication, dated July 17, 1952, from the Department of Fish and Game. This communication suggests several revisions for the class definitions. Although the suggested revisions impinge mostly on classes of streams for which flow requirements were not requested by the Division, it seems desirable to present all of the considerations involved in the estimates submitted by the Department.

It must be pointed out that the Division of Water Resources does not necessarily concur in the position taken by the Department of Fish and Game, particularly with reference to the status of agricultural use of water. Regardless of the Department's contention, the Water Code of the State of California specifically states:

> "It is hereby declared to be the established policy of this State that the use of water for domestic purposes is the highest use of water and that the next highest use is for irrigation." Div. 1, Chap. 1, Sec. 106, ed. of 1951.

The second communicaton from the California Department of Fish and Game, dated August 1, 1952, consists of estimates of stream flow prepared by the Department, together with explanatory comments regarding some of the streams and contemplated developments. It should be pointed out that the Department considers these estimates preliminary and subject to revision.

STATE OF CALIFORNIA
SACRAMENTO 14

Inter-Departmental Communication

To: Mr. A. D. Edmonston, *State Engineer*
Department of Public Works
Division of Water Resources
Public Works Building
Sacramento 14, California

Date: July 17, 1952

Subject: Water Requirements for Protection and Maintenance of Fish Life

From: Division of Fish and Game

Since receipt of your inter-departmental communication of April 10, 1952, our staff has devoted considerable further study to flow requirements necessary to maintain fish life in various streams and at specific points in other streams. Our recommendations for such flows were requested by you, in your memorandum of November 9, 1951, for use in connection with Bulletin No. 2 of the Statewide Water Resources Board investigation of ultimate water requirements.

In your above memorandum you grouped the streams of California into four classes as regards water requirements for fish life. These classes were proposed as follows:

Class 1. Streams which will be developed for recreation only, with the use of water for the preservation of fish life to be paramount.

Class 2. Streams which will be developed for multiple purposes, including the maintenance of fish life.

Class 3. Streams of such present erratic flow that there is no fish life, or the demand for water for municipal or agricultural uses is so great that no water can be allocated for maintenance of fish life.

Class 4. Streams of such small flow that estimates will not be prepared.

The Department of Fish and Game has carefully considered the proposed classes suggested above and is in general agreement with the classes as proposed. However, the Department of Fish and Game considers it imperative that the classes be further defined. For this reason the Department of Fish and Game has prepared its own definition of the various classes into which California streams may fall as regards water requirements for fish life. The essential definitions of Classes 1, 2 and 4 of the Division of Water Resources are followed but expanded.

A major disagreement between the classifications exists regarding the classification of water for agricultural use. The Department of Fish and Game can not agree that water for agricultural use should have complete priority over the use of water to maintain fish life and recreational values. As will be seen below the Department of Fish and Game classifies the agricultural use of water as one of the multiple uses of water, which include: power generation, flood control, the maintenance of fish life, recreation, and other beneficial water uses. Water for domestic use is considered to be the only use which takes complete priority over all other uses.

The classification of streams which is given below is recommended for inclusion as a permanent policy for streams in the California Water Plan. We believe that *the Department of Fish and Game must be consulted regarding the classification or change of classification of any streams.*

No attempt is being made at this time to classify all of the streams in California into one or another of these classes. The Department of Fish and Game will cooperate with the Division of Water Resources in the classification of individual streams as the need arises and upon request. It is understood, of course, that the classification of a stream may change either as a result of a change in the fishery or because of a change in the other water uses. Also, different sections of the same stream may fall into different classes.

CLASSES OF CALIFORNIA STREAMS

Class 1. Streams which would be reserved or developed primarily for the maintenance and development of fish life and other recreational uses. These streams fall into several categories.

(a) Those already set aside as inviolable, usually by Federal or State law. Examples: under Federal law, streams in National Parks and in wilderness areas; waters of the Klamath Fish and Game District, by State initiative measure. In most of these cases the aesthetic and recreational values are considered to transcend any other water uses, and past and possible future attempts to utilize these streams for other purposes have been and will be met with vigorous opposition by the public.

(b) Those where the economic value of the fishery alone outweighs any other present or contemplated economic use. Example: Rock Creek in Mono and Inyo counties.

(c) Those streams of special value as nursery waters for sport and commercial food fishes which spend a part of their life in the ocean. Examples: Big River and Noyo River, Mendocino County, and Deer Creek and Mill Creek, Butte County.

(d) Streams in which all or the major portion of the flow has been created by the Department of Fish and Game for the express purpose of maintaining fish life and recreational values.

Two facts should be emphasized regarding the waters falling into Class 1:

(1) There are relatively few such waters now and their number is more apt to decrease than increase; and,

(2) In many instances the water from these streams is available for other uses in the lower portions of the drainages.

Thus, while this is an important class, it affects only a small portion of the total waters in the State and, consequently, only a correspondingly small portion of the State's inland fishery resource.

Class 2. Those streams which will be developed for multiple-purpose use, including preservation and expansion of recreational and fisheries uses wherever possible.

Class 2 will include most of our major rivers and all streams where there is a conflict between use of the water to preserve or develop fisheries values and other use or uses, such as: power generation, irrigation, flood control, salinity control, waste disposal, etc. None of these other uses has complete priority *per se* over the use of water to maintain fish life. In each case of the development of a stream for multiple-purpose use, every possibility for the protection and/or development of a fishery will be investigated and integrated with the development of other water uses.

Proper consideration of the fishery resource must be given *early in the project planning stage* to such matters as flow releases, fish protective devices, operation of a recreational pool, etc., if maximum effectiveness and true multiple use is to be obtained. It must be recognized that the recreational benefits to be lost or to be gained *may be comparable to or may outweigh* the more easily evaluated economic benefits.

While it is true that in some multiple-purpose projects little consideration can be given to fish life, it is also true that in many such projects an additional beneficial use may be gained by proper consideration for a fishery, and that this gain may be achieved in a manner compatible with other water uses. For this reason it is imperative that the Department of Fish and Game be consulted in the preliminary project planning stage and be included as one of the project planning agencies.

Class 3. Streams of such present intermittent or erratic natural flow that there is no existing fishery.

Utilization or development of these waters may be undertaken without further consideration of fish life requirements except in the case of impoundments. When impoundments are made upon such streams, consideration should be given to the establishment of permanent minimum pools for fish life. Typical examples of this category would be the low-level intermittent streams in the Central Valley and in Southern California. In general, streams in Class 3 must have no surface flow for at least part of the year in years of normal rainfall.

Class 4. Streams in which the demand for water for domestic uses is so great that no water can be allocated for maintenance of fish life or recreational values, providing the following statement is first considered.

The value of water for domestic uses is recognized as having the highest priority, but before any stream or water source is placed in Class 4 (whereby the entire flow is used for domestic purposes) every possible means of providing water for fish life and recreation should be exhausted to the fullest extent by all parties concerned during the planning stages of the project development.

Class 5. Streams of such minor importance, at the present time, for uses other than for recreation, including the maintenance of fish life, that the problems of conflicting uses have not arisen. This is ordinarily the result of geographical location, small flow, or both.

Streams in Class 5 may, however, be very important recreational waters, supporting wild or artificially stocked fish populations. For example, the bulk of the small streams in National Forests fall into this category. Individually these streams are unimportant but collectively they form an important part of the inland fishery resources of the State.

In general, a list will not be prepared nor required for the streams in this class, nor will special investigations of them be made. Some of these waters undoubtedly will require reclassification as a result of population growth, increased recreational values, and development of other water uses. When this occurs the stream will be taken from Class 5 and placed in another class.

We trust that the modifications of your proposed classes which we have suggested above will meet with your approval, and shall try to send you our specific flow recommendations by the end of the month.

Seth Gordon
Director

STATE OF CALIFORNIA
SACRAMENTO 14

Inter-Departmental Communication

To: Mr. A. D. Edmonston, *State Engineer*
Department of Public Works
Division of Water Resources
Public Works Building
Sacramento 14, California

Date: August 1, 1952

Subject: Water Requirements for Protection and Maintenance of Fish and Game in Connection with State Water Plan

The Department of Fish and Game has prepared the enclosed flow estimates for the maintenance of fish life as requested in your memorandum of November 9, 1951. We are also transmitting at this time the estimated water requirements for our game populations, including waterfowl.

These estimates must be considered preliminary as they are subject to review and possible modification by the Fish and Game Commission. Please refer to our memorandum of July 17, 1952, for additional comments on the water requirements of fish and wildlife.

Seth Gordon
Director

STATE OF CALIFORNIA
SACRAMENTO 14

Inter-Departmental Communication

To: MR. A. D. EDMONSTON, *State Engineer*
Department of Public Works
Division of Water Resources
Public Works Building
Sacramento 14, California

Date: August 1, 1952

Subject: Water Requirements for Protection and Maintenance of Fish and Game in Connection With State Water Plan

In our interdepartmental communication of July 17, 1952, we set forth the general comments of the Department of Fish and Game on the flow requirements necessary to maintain fish life in various streams of California with particular emphasis on the proposed stream classifications to be used in Bulletin No. 2 of the State Water Plan now being developed by the Water Resources Board. We are now transmitting the specific flow estimates that were requested in your letter of November 9, 1951, together with our estimates of the ultimate water needs of the game resources of California.

PART I. WATER REQUIREMENTS FOR FISH LIFE

The Department of Fish and Game was originally requested to submit estimates of the amounts of water needed for the maintenance of fish life on certain streams and at specific points on other streams. As we stated in our memorandum of July 17, we believe that the classification system originally proposed should be more clearly defined and expanded. We believe the large number of streams which are extremely important to the Department of Fish and Game that were not included in the original request should definitely be considered in the preparation of any comprehensive State plan of water resources development. For example, we believe that there are a considerable number of streams which should be reserved or developed primarily for fish life or recreational development in addition to the few listed in your Class I. In any case we do not want to create the impression that our interest is confined only to the requested streams or that we are "writing off" any other stream for which flow recommendations are not made at this time. Also we feel that we must retain the right to adjust our recommendations upward or downward as additional information is developed by our fisheries management staff as we have not had personnel available to carry out anything but cursory investigations of these streams. We believe, however, that these flow estimates tend to be on the conservative side.

Flow estimates have been prepared for all streams requested except the Central Coastal Streams from the Big Sur River to Santa Rosa Creek. In our opinion no development is possible on these streams and the highest use of this water is probably for the rather limited amount of recreation furnished at the present time. These streams support runs of steelhead at the present time and it is felt that the summer recreational use will increase in the future.

The flow estimates given below are those which the Department of Fish and Game believes should be available for fish life in years of normal or nearly normal run off. With these flows the existing fish populations can be maintained but more water would be required to increase the population, probably in conjunction with other habitat improvement. Likewise, these estimates are not necessarily the minimum flow which could be endured for a single season without seriously damaging resident or migratory fish. To be of value, of course, these releases must actually be available to fish and not merely flows which pass a certain point only to be diverted a short ways down a stream. We recognize that in those years when there is a water shortage of such degree as to require the curtailment of water for agricultural use that the water available for the fisheries resources would be curtailed to the same degree. The exact details of such a flow reduction, however, will have to be carefully worked out for each stream. Under extreme drought conditions a small amount of water for fish life can be made to accomplish a great deal more if it is regarded as storage to be released during the season at times and in quantities requested by our fisheries management staff. This is particularly true on those streams which support anadromous fishes such as salmon and steelhead which require water during the period of migration.

In the original listing of streams furnished by Mr. Edmonston the flows were requested at certain gauging stations on the lower portions of the streams.

Some of the gauging stations listed are within the present range of migratory fishes but are of little use as a point of reference for flows required for fish life. For example, one of the points requested was on the American River below Folsom Dam. Now that Nimbus Dam is under construction the flows of interest will be those below Nimbus and the flow between Folsom and Nimbus will be of little importance. In such instances we have taken the liberty of recommending flows at the spot which is regarded as the key point on the stream for the maintenance of the fisheries.

It is also assumed that the flows recommended will be relatively stable. Widely fluctuating flows such as those below power plants that are utilized for peaking purposes without re-regulation will have a fish-carrying capacity approximately equal to the lowest flow of the cycle. Fluctuating flows of this type also cause damage by stranding fish when the flow is abruptly reduced. Another important point is that the actual flow releases that will be necessary will ultimately depend upon the plan of water resource development. For example, an impassable dam constructed near the mouth of a salmon and steelhead stream will obviously make a great difference in the flows previously estimated as being necessary for maintaining the run at some point upstream.

The Central Valley salmon rivers are probably the streams of greatest interest to your office and the Department of Fish and Game at the present time. It is felt that the following comments on these streams will be of value and will supplement the actual flow recommendations.

1. Sacramento River

Copper pollution entering this river below Shasta Dam may make it necessary to increase releases above the minimum flows given in order to dilute the copper to the point where it is non-lethal to fish. An investigation of this problem is underway at the present time.

2. Feather River

Present water conditions as they affect salmon and steelhead:

In the main stream above the Sutter Butte Dam there is ample water at all times during any but the driest years.

Below the Sutter Butte Dam the flows are usually adequate when there is no diversion at the Great Western or Sutter Butte Canals. When the diversion at Sutter Butte reduces the river flow to less than 400 c.f.s., that portion of the stream is of little use to salmon and steelhead, except as an avenue of escape to the upper portions of the stream. In the summer the river is completely diverted (except for the leaks in the Sutter Butte Dam), and the stream soon becomes entirely too warm for salmonids. Spring run salmon enter the Feather River from March to June, but the only ones which have much chance of survival are those which have passed the Sutter Butte Dam before the start of total diversion. The spring run salmon spend the summer in deep holes and spawn in the fall. Fall run salmon enter the Feather from September through December. The heaviest spawning is in November. The young of both runs migrate downstream from late January into June with the heaviest movement in February and March. Those fish which start their migration before the irrigation season have an excellent chance of survival. Judging from the action of salmon in other streams, there is little chance for those which are more than a few miles from the Sacramento River when total diversion starts. Suddenly reducing the flow to summer level seems to stop the migration even when there is enough return water to make such a migration theoretically possible. The indications are that few if any salmon are able to survive the heat of a Central Valley summer in return irrigation water.

The Probable Effects of the Oroville Dam

Oroville Dam will make many miles of spawning stream unavailable to salmon and steelhead. This is a distinct handicap. On the other hand, the dam could be so used as to improve conditions below it. If water is drawn from lower levels of the pool, it will presumably remain cold all summer. This would be a benefit to the spring run and early fall run fish. The later fall fish would not be affected as they normally encounter cold water when they arrive. If the reservoir is drawn down to the point where it starts discharging warm water into the river, the result could be the loss of the major part of that year's run. If such disasters do not occur too often, the natural resiliency of the fish should overcome the effect.

3. Yuba River

There is a spring and fall run of salmon and a run of steelhead in this stream. In past years fish have been handicapped by the lack of a functional fish ladder at Daguerre Point Dam and by inadequate flows below the dam. The Department of Fish and Game has recently completed two functional fish ladders over the dam, and anadromous fish are able to migrate as far upstream as the Narrows Dam. Bringing the Yuba under more complete control will, of course, result in greatly reduced flows in the spring. In the past these flows have been used by spring run fish and during periods of flow exceeding 10,000 second feet some fish have been able to get above the Daguerre Point Dam even without fish ladders. If the spring run is to continue to survive in this stream, it will be necessary to provide an adequate flow of water below Daguerre Point Dam in May and June. If the flows below Daguerre Point are cut much below 350 second feet, it seems probable that the spring run will gradually disappear. With flows in excess of 500 second feet the run should build up. Both the spring and fall runs require adequate water to cover the gravel and permit spawning during the period from October through December. An adequate downstream flow from January through May is required to hatch the eggs and enable the young to reach the Feather and Sacramento Rivers. During the period from July to September a relatively small flow needs to be provided below the Daguerre Point Dam for resident fish. Elimination of water flow at this time would cause less damage than at any other period of the year.

4. Bear River

At the present time this river has for all practical purposes no salmon run. We would like to explore the possibility of establishing a run in this stream and determine the amount of water which would be required. In the event that there would seem to be little chance of securing any appreciable flow during a period from October 1 to June 1, we would then feel there was no point in making such an investigation.

5. American River

If no dam were to be built below the town of Folsom, it would be a relatively simple problem to maintain a good salmon run in the American River and with adequate flows the steelhead might be able to spawn successfully in this section of stream. At the present time, however, the construction of Nimbus Dam appears to be a certainty. This structure will cut off or destroy about 70 per cent of the spawning grounds remaining below Folsom. The problem thus becomes one not only of securing sufficient water, but of creating artificial spawning grounds (made of dredger tailings) or of building conventional type hatcheries as well. It will be some time before we have any final answers on what can be accomplished with the stub of this once excellent salmon stream. In the interim we are proposing the water releases listed in the tables.

6. Cosumnes River

At the present time this is a marginal salmon stream. Moderate improvement in conditions might transform it into a moderately good stream. Any worsening of conditions would be apt to eliminate the runs almost entirely.

7. Mokelumne River

This stream has suffered from copper pollution, winery pollution, gold dredgers, illegal spearing, and from a bad fish block at the Woodbridge Dam. Potentially, it is one of the best tributary streams in the valley. There remains a small fall run which should be capable of growing into a much larger run.

At present there is almost no spring run, but we can see no reason why the stream could not produce a large spring run, if it were given proper help. This help would have to include several plantings of fish and a more reliable flow of water below Woodbridge Dam during May and June. If no effort is made to build up a spring run it would still be necessary to provide water below Woodbridge for the downstream migration of young fall run salmon. Probably this flow should last until the end of May. If the various hazards to fish life on the Mokelumne River can be controlled the present flow below Pardee Dam should be able to suport 20 to 40 times as many salmon as are now using this stream. The flows given below refer to the salmon producing potential of the stream rather than to the present run, since water flow has not been the most important factor in limiting the run in recent years.

8. Stanislaus River

This is an excellent fall salmon stream. There are the bare remnants of a spring run, and a small summer release might make it possible for this run to increase in size. The summer flow in question would have to be in the canyon above Knight's Ferry since that is the only part of the stream which would be satisfactory for spring run salmon on a low flow. The stream in the past has suffered from pollution and from widely fluctuating power releases at Melones Dam during the spawning season.

9. Tuolumne River

In recent years the Tuolumne River has had one of the best fall salmon runs in the State. It has almost no spring run and there would seem to be a little prospect of developing one. The worst problem has been that of pollution caused by industrial waste during the canning season at the city of Modesto. Another detriment has been a severe drop in the water level occurring about January 1. From about October 15 to December 31 the stream usually carries on the order of 1,000-1,500 second feet. The salmon spawn during this period. In January the flow is so greatly reduced that many salmon nests are left high and dry.

10. Merced River

This stream is at present a marginal salmon stream for both the spring and fall run. The area of good spawning gravel is tremendous and a slight increase in the water available at key times could well result in increasing the salmon run several hundred percent. At present during the irrigation season water is released in quantity from Exchequer Dam, passes through the power house at Merced Falls, and is picked up at the Merced Irrigation District diversion. A flow of about 135 second feet goes downstream to a gravel diversion dam at Snelling where the majority of it is diverted. There are other gravel dams and their diversions and one concrete dam found downstream. In the fall at the end of the irrigation season

ESTIMATED MINIMUM FLOWS REQUIRED TO MAINTAIN GAME FISH POPULATIONS AT PRESENT LEVELS

Name of stream and locality	SUMMER (*April-Sept.*)	WINTER (*Oct.-March*)
Class I Streams		
Gualala River	10 c.f.s.	200 c.f.s.
Garcia River	10 c.f.s.	200 c.f.s.
Navarro River	15 c.f.s.	350 c.f.s.
Big River	15 c.f.s.	200 c.f.s.
Noyo River	10 c.f.s.	200 c.f.s.
Ten-Mile River	20 c.f.s.	300 c.f.s.
Mattole River (possible power development)	40 c.f.s.	350 c.f.s.
Bear River (possible power development)	10 c.f.s.	200 c.f.s.
Redwood Creek (possible power development)	40 c.f.s.	250 c.f.s.
Carmel River	15 c.f.s.	200 c.f.s.
Big Sur River	35 c.f.s.	200 c.f.s.
Class II Streams		
1. Smith River		
a. At Fort Dick	250 c.f.s.	1,250 c.f.s.
b. South Fork at confluence with main stream	200 c.f.s.	800 c.f.s.
c. North Fork at confluence with main stream	100 c.f.s.	450 c.f.s.
d. Main stream above confluence with North Fork	150 c.f.s.	1,000 c.f.s.
2. Klamath River		
a. At Klamath	1,200 c.f.s.	2,000 c.f.s.
b. Trinity River at confluence with main stream	250 c.f.s.	1,000 c.f.s.
c. Main stream above confluence with Trinity River	650 c.f.s.	1,200 c.f.s.
d. Salmon River at confluence with main stream	150 c.f.s.	300 c.f.s.
e. Main stream above confluence with Salmon River	500 c.f.s.	1,000 c.f.s.
f. Scott River at confluence with main stream	100 c.f.s.	250 c.f.s.
g. Main stream above confluence with Scott River	500 c.f.s.	1,000 c.f.s.
h. Main stream at confluence with Shasta River		
without daily fluctuation	1,000 c.f.s.	1,000 c.f.s.
with daily fluctuation (high)	1,500 c.f.s.	1,500 c.f.s.
(low)	500 c.f.s.	500 c.f.s.
i. South Fork Trinity River at confluence with Trinity River	100 c.f.s.	1,000 c.f.s.
j. Trinity River at Lewiston		
January 400 c.f.s.	July	200 c.f.s.
February 400 c.f.s.	August	200 c.f.s.
March 400 c.f.s.	September	200 c.f.s.
April 300 c.f.s.	October	300 c.f.s.
May 300 c.f.s.	November	600 c.f.s.
June 300 c.f.s.	December	400 c.f.s.
3. Mad River		
a. At mouth	15 c.f.s.	350 c.f.s.
4. Eel River		
a. Main stream above confluence with Van Duzen River	100 c.f.s.	500 c.f.s.
b. Van Duzen River at confluence with main stream	25 c.f.s.	150 c.f.s.
c. Van Duzen River at Bridgeville	20 c.f.s.	100 c.f.s.
d. Main stream above confluence with South Fork	100 c.f.s.	150 c.f.s.
e. South Fork at confluence with main stream	50 c.f.s.	200 c.f.s.
f. Middle Fork at confluence with main stream	40 c.f.s.	350 c.f.s.
g. Main stream above confluence with Middle Fork	20 c.f.s.	125 c.f.s.
h. Eel River at Van Arsdale Dam	5 c.f.s.	100 c.f.s.
5. Russian River		
a. Main stream at mouth	200 c.f.s.	500 c.f.s.
b. Main stream at Ukiah	100 c.f.s.	250 c.f.s.
6. Sacramento River	(*Sept.-Dec.*)	(*Jan.-Aug.*)
a. Below Shasta Dam	4,000 c.f.s.	3,000 c.f.s.
b. Above confluence with Feather River	4,000 c.f.s.	4,000 c.f.s.

7. Feather River			
a. At driest point below Sutter-Butte Dam	(*Sept. 15-Dec.*)	(*Jan.-June*)	(*July-Sept. 14*)
	1,200 c.f.s.	900 c.f.s.	250 c.f.s.
b. At Oroville (after Oroville Dam-cold water)	600 c.f.s.	400 c.f.s.	400 c.f.s.

Name of stream and locality			SUMMER (*April-Sept.*)	WINTER (*Oct.-March*)
Class II Streams—Continued				
7. Feather River—Continued				
c. East Branch North Fork at confluence with North Fork			(*Mar.-Oct.*) 25 c.f.s.	(*Nov.-Feb.*) 200 c.f.s.
d. Middle Fork at Sloat			45 c.f.s.	110 c.f.s
8. Yuba River				
a. Below Narrows Dam	(*Oct.-Dec.*) 500 c.f.s.	(*Jan.-Apr.*) 500 c.f.s.	(*May-June*) 300 c.f.s.	(*July-Aug.*) 500 c.f.s.
b. Driest point below Daguerre Point	500 c.f.s.	350 c.f.s.	500 c.f.s.	75 c.f.s.
9. Bear River				
No salmon run but see previous paragraph 4.				
10. American River				
a. At Folsom (below Nimbus Dam)		(*Sept. 15-Dec.*) 750 c.f.s.	(*Jan.-Feb.*) 500 c.f.s.	(*Mar.-Sept. 15*) 350 c.f.s.
b. North Fork above confluence with Middle Fork			50 c.f.s. minimum at all times	
c. Middle Fork above confluence with North Fork			60 c.f.s. minimum at all times	
d. South Fork at Coloma			100 c.f.s. minimum at all times	
11. Cosumnes River				
a. Below Bridgehouse Dam		(*Nov.-Dec.*) 150 c.f.s.	(*Jan.-May*) 75 c.f.s.	(*June-Oct.*) Live stream to Hiway 99
12. Mokelumne River				
a. Below Pardee Dam		(*Sept. 15-Dec.*) 500 c.f.s.	(*Jan.-June*) 300 c.f.s.	(*July-Sept. 14*) 300 c.f.s.
b. Below Woodbridge Dam		250 c.f.s.	150 c.f.s.	25 c.f.s.
13. Stanislaus River				
a. Below Tulloch Dam		(*Oct.-Dec.*) 150 c.f.s.	(*Jan.-May*) 100 c.f.s.	(*June-Sept.*) 10 c.f.s.
14. Tuolumne River				
a. At La Grange	(*June-Sept.*) 25 c.f.s.	(*Sept. 15-Oct. 15*) 500 c.f.s.	(*Oct. 15-Dec.*) 1,000 c.f.s.	(*Jan.-May*) 700 c.f.s.
15. Merced River				
a. At driest point below Exchecquer	(*Oct.-Dec.*) 35 c.f.s.	(*Jan.-Apr.*) 35 c.f.s.	(*May-June*) 300 c.f.s.	(*July-Sept.*) 15 c.f.s.
16. San Joaquin River				
a. At Hills Ferry			500 c.f.s.	minimum
b. At Vernalis			1,000 c.f.s.	minimum
17. Susan River				
a. At Susanville			(*Oct.-Mar.*) 25 c.f.s.	(*Apr.-Sept.*) 50 c.f.s.
18. Truckee River				
a. At Tahoe City			25 c.f.s.	minimum
b. At California Stateline			25 c.f.s.	minimum
19. Carson River				
a. West Fork at Stateline			15 c.f.s.	minimum
b. East Fork at Stateline			15 c.f.s.	minimum
20. Walker River				
a. West Fork at Stateline			30 c.f.s.	minimum
b. East Fork at Stateline			40 c.f.s.	minimum
21. Owens River				
a. Above Tinemaha Reservoir			100 c.f.s.	minimum

the water is cut down to about 35 second feet at Exchequer. Often the upper part of the stream is so low that salmon have difficulty finding satisfactory places to spawn and even more difficulty in making their way upstream from the mouth of the river. Any reduction of this 35 second feet flow might completely eliminate both spring and fall runs.

In the spring, Exchequer reservoir often spills, and flows in excess of 1,000 second feet going down the river channel. Spring run migrants find this cold snow water to their liking and many of them do not continue upstream past Snelling. This flow generally stops very suddenly when the spill ceases. The salmon which have gotten past the Merced Irrigation District Dam have an excellent chance of survival. Those which are between Merced Irrigation District Dam and Snelling have a fair to good chance. Those which are downstream from Snelling are almost certain to be killed by the high summer temperatures, and they have almost no chance to migrate upstream to safety through the low flows and gravel dams below Snelling. The water currently wasted in the area downstream from Snelling by poor water management practices would greatly improve the salmon run if it were allowed to stay in the river instead of being totally diverted at intervals and allowed to leak back into the river from poorly kept ditches.

11. San Joaquin River

The flows given for this stream were intended to give the amount of water required at Hills Ferry and Vernalis to keep resident fish in good condition and to enable migratory fish to pass through on their way to the spawning grounds in the various San Joaquin tributaries. Our knowledge of flows required in this section is very limited. The necessary flow below Friant Dam has previously been discussed at length and as these estimates were not requested have not been included.

PART II. WATER REQUIREMENTS FOR THE MAINTENANCE OF GAME

Game water requirements have been subject to being overlooked or to relegation to a place of minor importance in any allocation of water. However, minor as the total water required for the maintenance of game numbers might be, still a definite, firm requirement is present, and should be recognized in any long range planning of water allocations. That game and game interests have a firm part in the economy of the State is evident both by the governmental recognition given to this endeavor, and by the large amounts of time and money invested in the fostering and pursuit of game by the public of the State.

That game water requirements should be planned for is implied in the State Water Resources Act of 1945, Chapter 1514 of the Statutes of 1945, "an act declaring the public policy of the State, relating to flood waters and control, conservation, and the use of the State's water resources." Section 2 of this Act states, "In studying water development projects, full consideration shall be given to all beneficial uses of the State's water resources, including preservation and development of fish and wildlife resources, and recreational facilities, but not excluding other beneficial uses of water."

It is the purpose of this report to state in general, on a statewide basis, what game water requirements are, and in the case of waterfowl, to state specifically the local needs in important areas in California.

For simplification, game water requirements will be stated in two general categories: water for big game and upland game, and water for waterfowl and other aquatic wildlife.

I. Water for Big Game and Upland Game

In general, water supplies for these game species, such as deer, antelope, quail, dove, etc., are not seriously threatened on a statewide basis at present under existing agricultural and economic practices. Locally threats to continued existence of these species are present, and with increasing economic development of marginal lands, will become an ever increasing hazard to continued existence of these species throughout the State.

These species do not require large quantities of water in any one spot; rather, their needs are best expressed in the form of small quantities measured in gallons rather than acre feet. The supply, however, must be widespread and scattered over the range of these animals in proper relation to basic food and cover sources.

One of the principal threats to the supply of water for these species lies in the unwise use of springs by livestock interests, and to an increasing degree by mining or pseudo-mining interests in arid regions. This threat is more important in the desert area of southeastern California than in other sections but is present to some degree throughout the drier foothill areas of the State. It reaches its height in instances where a livestock operator through a water filing or otherwise virtually locks up all the water in a spring or springs for a rather large area of range land. Such use often takes the form of completely utilizing the flow of a spring by boxing it, and piping the flow to a trough that is inaccessible to small game by reason of its location away from cover and feed, or by its construction in such a manner that game cannot reach the water without the hazard of drowning in the process. In most of these cases, some small inexpensive provision could be made for wildlife water; this provision would not affect in any material degree the water that would be available for livestock, and would give measurable benefits to the wildlife in surrounding areas. Water applications for the use of springs in desert or semi-desert areas should have a provision that adequate water for wildlife should be left. The adequacy of such supply should be determined by the representatives of the official wildlife agency of the State.

Another more recent threat to game in foothill areas has been the recent controversy between large irrigation interests in valley lands versus livestock operators in the watershed areas that supply water for the irrigation districts. In some instances this has taken the form of questioning the rights of watershed land holders to build small stock dams on drainages flowing into big reservoirs on the theory that such small dams use an appreciable quantity of water that is subject to the prior right of downstream users. This subject has not yet affected fish or game interests to any considerable degree to date, but could conceivably do so in the future with the current increase in farm pond and stock-dam programs that are being fostered by fish and game interests. In this instance, game officials will be interested in seeing that proper water supplies are developed and maintained for upland and big game in watershed areas.

Water needs for this group of game varies considerably in different sections of the State. Areas of high potential game populations that abound in cover and desirable feeds have higher water needs than do areas of low game productivity. Within the generality above, areas that are desert, or semi-desert, in climate have higher needs for free water than do lush coastal areas. These generalities are expressed in Table I "Big Game and Upland Game Water Requirements."

Table I lists the water requirements by counties for upland and big game species. The needs are expressed in gallons per square mile. This gallonage figure might best be expressed as "gallons of free water available daily per square mile." It does not necessarily mean for instance that throughout a year, or even throughout a summer, that there must be a flow of say eight gallons per day per square mile. It does mean, however, that at some crucial, hot, dry time, or times during a year that a flow of eight gallons per day will be necessary and will be used by wildlife.

It should be emphasized that proper distribution of this water is paramount. Eight gallons of water per square mile if distributed on the basis of 800 gallons located on one section leaving 99 sections dry would be of little use. Ideally over most of the State having populations of deer, quail, etc., there should be available water for every quarter section, or at least for every section in drier areas.

One additional point with respect to the relation between game and water development should be made. It does not have to do with game use of water, but rather with hazards that water development projects may impose on game. The construction of open diversion ditches often creates a hazard to wildlife, especially so in regard to deer. Legislation would be desirable, making it mandatory for any corporation, irrigation district, water company, or any other party or parties constructing such ditches or other impoundments to install, or cause to be installed suitable escape ramps for the preservation of wildlife.

II. Water for Waterfowl and Other Aquatic Game

It is in the needs of water for waterfowl and other game species requiring wet lands for their existence that man's agricultural and economic water needs have made the greatest inroads. Vast acreages of former marsh or semi-marsh lands have been drained for farming or other purposes, pushing these species into a small existing area which in turn is further subject to demands for more land and more water. Waterfowl are vitally dependent on free water over productive land areas. Their continued existence depends on planned reservation of water for their use. Other minor aquatic wildlife species, such as shorebirds, muskrat, beaver, etc., will benefit from any planning for waterfowl.

In order to allocate water for these species, such allocation must be done for specific areas of the State, since waterfowl have definite habits and needs for certain types of lands and feeds which cannot be met with alternate situations. In other words, wintering grounds for waterfowl must be met in warm valley areas capable of growing good reliable foods. They cannot be met on mountain areas, or on areas of poor winter climate or inferior soil. Farming development has taken over the vast majority of lands formerly available to these species; the needs found below are allocated to lands that remain available in some measure for waterfowl. Provision must be made with as much speed as possible to see that not only lands, but water for these lands are devoted to waterfowl.

That California has in this matter an obligation not only to her sister States of the Pacific Waterfowl Flyway, but to our neighbor Nations to the North and South, has been brought out by many waterfowl authorities. This State has been the traditional wintering ground for vast numbers of birds of the Pacific Flyway. It has assumed this position of responsibility to the birds, if such it may be called, by virtue of its valley areas and their attendant winter climates. There is no substitute which will serve if these birds are to survive. It is with full realization of these facts that the needs of waterfowl for their continued existence are presented in Tables II and III.

Table II presents the needs for water for existing State waterfowl areas. Table III denotes needs for areas that have been proposed for State acquisition in order to perpetuate the resource. Whether or not the State acquires these areas, the needs for waterfowl will continue to exist if the waterfowl resource is to be perpetuated.

No mention is made of requirements for Federally operated areas. It is assumed that the U. S. Fish and Wildlife Service will list their needs for areas under their control.

It should be emphasized that the requirements shown in Table III are minimum. Even though these are tied to specific areas for reasons outlined above, there are in some instances possibilities of nearby alternates for some of the areas listed.

It will be noted that in the larger areas, both presently owned and those proposed for future acquisition, that provision is made for crop water. This is done in the interests of crop protection for surrounding agriculturalists as well as a primary food source for ducks.

Regarding competition between use of water for growing food crops for waterfowl and use of water for commercial agriculture, it is pointed out that

1. In most cases the growing of food crops for waterfowl is primarily for the purpose of protecting commercial agriculture from waterfowl depredation.

2. A number of existing and proposed projects are not in competition with farming since they are located below agricultural diversions. These are Grizzly Island, Suisun Refuge, Lake Earl, and Humboldt Bay. The water supply for Grizzly Island and Suisun Refuge is secured from Montezuma and Suisun Sloughs, tributaries to Suisun Bay.

3. The use of water for waterfowl in the Colorado River drainage is considered only slightly competitive with agriculture since drain and spill waters may be largely utilized.

4. The water needs in acre feet listed in some of the wet land areas such as Lake Earl and Clear Lake are large open bodies of water presently existing.

Accurate data on privately owned lands used for waterfowl purposes are lacking. The figure of 200,000 acres has been widely used and is herein used for purposes of this report.

Of these 200,000 acres, at least one quarter (50,000 acres) is located on tidelands or at the extreme lower ends of drainages where only tide or waste water is used.

The remaining 150,000 acres are here considered to depend in varying degrees upon the use of waters pertinent to the State Water Plan.

TABLE I

BIG GAME AND UPLAND GAME WATER REQUIREMENTS

(Quantities expressed in gallons per day per square mile needed for drinking water)

County	Area in square miles	Average gallons per sq. mi.	Total gals. per County	County	Area in square miles	Average gallons per sq. mi.	Total gals. per County
Alameda	840	4	3,360	Placer	1,484	8	11,872
Alpine	575	22	12,650	Plumas	2,361	20	47,220
Amador	568	15	8,520	Riverside	7,008	4	28,032
Butte	1,764	8	14,112	Sacramento	988	8	7,904
Calaveras	990	8	7,920	San Benito	1,476	12	17,712
Colusa	1,080	10	10,800	San Bernardino	20,055	4	80,200
Contra Costa	750	4	3,000	San Diego	4,207	4	16,828
Del Norte	1,546	8	12,368	San Francisco	42	0	0
El Dorado	1,891	15	28,365	San Joaquin	1,370	0	0
Fresno	6,035	7	42,245	San Luis Obispo	3,500	6	21,000
Glenn	1,460	10	14,600	San Mateo	470	0	0
Humboldt	3,507	8	28,056	Santa Barbara	2,450	4	9,800
Imperial	4,316	4	17,264	Santa Clara	1,355	12	16,260
Inyo	10,224	4	40,896	Santa Cruz	425	4	1,700
Kern	8,159	4	32,636	Shasta	4,050	22	89,100
Kings	1,375	4	5,500	Sierra	957	15	14,355
Lake	1,332	9	11,988	Siskiyou	6,078	22	133,716
Lassen	4,750	8	38,000	Solano	911	4	3,644
Los Angeles	4,000	4	16,000	Sonoma	1,540	10	3,850
Madera	2,140	6	12,840	Stanislaus	1,486	8	11,888
Marin	516	10	5,160	Sutter	611	4	2,444
Mariposa	1,580	10	15,800	Tehama	3,200	8	25,600
Mendocino	3,400	8	27,200	Trinity	3,276	8	26,208
Merced	1,750	6	10,500	Tulare	4,863	6	29,178
Modoc	4,097	26	106,522	Tuolumne	2,282	8	18,256
Mono	2,796	4	11,184	Ventura	1,850	4	7,400
Monterey	3,150	8	27,600	Yolo	1,017	8	8,136
Napa	800	12	9,600	Yuba	625	8	5,000
Nevada	982	8	7,856				
Orange	780	12	9,360	Totals	157,390	487	1,229,205

NOTE. Average gallons per square mile have been carried to the nearest gallon.
Gallons per square mile may mean two gallons per square mile in some watersheds and as high as twenty in others, depending upon the locality.

TABLE II

ANNUAL WATER REQUIREMENTS

Existing State Waterfowl and Management Areas

Area	Location (county)	Total acreage planned	Average acres crop	Water requirements for crops (acre-feet)	Storage (ponds) water area acres	Water required for ponds (acre-feet)	Total water required (acre-feet)
Madeline Plains W.M.A.	Lassen	5,176	660	4,620	1,420	9,940	14,560
Tule Res.	Lassen				3,100		3,100
Honey Lake W.M.A.	Lassen	5,000	3,466	19,928	1,566	8,244	28,172
Gray Lodge	Butte	6,500	2,000	9,000	2,000	12,000	21,000
Suisun	Solano	1,900			1,500	9,000	9,000
Grizzly Island W.M.A.	Solano	8,600	1,200	3,000	3,500	12,250	15,250
Los Banos	Merced	3,000	1,500	7,125	1,000	4,000	11,125
Tupman	Kern	1,000	500	1,750	250	875	2,625
Imperial W.M.A.	Imperial	4,400	1,700	6,930	25	157	7,087
Imperial Refuge No. 1	Imperial	2,000			2,000	10,000	10,000
TOTALS		37,576	11,026	52,353	16,361	66,466	121,919

TABLE III

ANNUAL WATER REQUIREMENTS

Proposed Waterfowl Management Areas

Area	Location (county)	Proposed acreage	Average acreage crop	Water requirements for crops (acre-feet)	Storage (ponds) area (acre-feet)	Water required for ponds (acre-feet)	Total water required (acre-feet)
Upper Butte	Butte	5,750	2,000	8,500	2,000	8,000	16,500
San Luis Is. W.M.A.	Merced	6,800	3,000	13,320	2,000	6,432	19,752
Madera W.M.A.	Madera	5,000	2,000	8,550	1,500	5,250	13,800
Tupman W.M.A.	Kern	4,000	2,000	8,550	500	2,000	10,550
Pit River W.M.A.	Shasta	4,000	1,000	4,000	2,000	8,000	12,000
Lake Earl Mgt. Area	Del Norte	400	400	800			800
Humboldt Bay Mgt. Area	Humboldt	1,600	1,600	3,200			3,200
Lower Colorado River Mgt. Area	Imperial (Palo Verde)	5,000					22,500
San Luis Wasteway	Merced	2,700	1,250	2,200	1,500	2,625	4,825
Carlsbad Lagoon	San Diego	250	50	100	200	700	800
San Antonio Creek	Santa Barbara	200			200	600	600
TOTALS		35,700	13,300	49,220	9,900	33,607	105,327

Private lands are rarely devoted exclusively for waterfowl purposes so that these lands can be considered to be in dual use, the most common pattern being livestock grazing combined with waterfowl shooting. It is the general custom to apply two-thirds of the available water in the fall, just prior to and during the hunting season. The remaining one-third is used in the spring.

Benefits derived from this type of water application should not be charged to two-thirds waterfowl and one-third to livestock grazing. The fall water serves to charge the soil, and start vegetation growing in late winter and early spring; without it, the spring applied water would be of far less livestock value. It is felt only fifty per cent of the water reserved for use on these lands can be justifiably charged to waterfowl.

In the "Grasslands" of the San Joaquin Valley, one foot of water per acre per year has given reasonably satisfactory operation of the area as a grazing and gun club operation. This figure applied to the 150,000 acres in California devoted to similar use will require reservation of 150,000 acre feet of water, half of which is chargeable to waterfowl benefits.

Table IV denotes water requirements on minor waterfowl lands throughout the State, mostly in coastal areas. These are generally small in size and are by and large under private control. Many of them may be desirable for future acquisition by the State, but in the main, as long as water for ducks is provided, they may well serve their end for waterfowl by remaining in private ownership.

Based on the above principles, the total water needed for game use in California (exclusive of needs on Federally operated waterfowl lands) is estimated as follows:

(a) Upland Game Lands—8.75 gals. per sq. mile—1,229,205 gallons	
(b) Existing State Waterfowl Areas	121,919 ac. ft.
(c) Proposed Waterfowl Areas	105,327 ac. ft.
(d) Other Wet Lands	964,400 ac. ft.
(e) Private Waterfowl Lands	75,000 ac. ft.
TOTAL	*1,266,646 ac. ft.

NOTE: Estimates given here are subject to revision wherever and whenever it is deemed necessary to conform to changes in land and water uses.
* This total figure applies to waterfowl lands only.

TABLE IV

WATERFOWL WATER REQUIREMENTS IN OTHER AREAS NOT LISTED ABOVE

Area	County	Acreage	Water Required (Acre-feet)
Lake Earl	Del Norte		10,000
Fresh Water Lagoon	Humboldt		3,000
Stone Lagoon	Humboldt		2,400
Big Lagoon	Humboldt		5,000
Clear Lake	Lake		200,000
Butte Sink	Butte and Colusa	24,000	48,000
Grass Lands	Merced and Madera	98,234	33,000
South Bay	Santa Clara and Alameda	2,000	3,000
Dune Lakes	San Luis Obispo	1,000	2,000
Morro Bay	San Luis Obispo	6,000	1,500
Santa Maria River (Mouth)	San Luis Obispo	1,500	3,000
Elkhorn Slough	Monterey	1,200	2,000
Salinas River (Mouth)	Monterey	1,000	1,500
Santa Maria River	Santa Barbara	250	800
Guadalupe Lake	Santa Barbara	600	1,500
Santa Ynez River	Santa Barbara	200	500
Santa Clara River (Including McGrath Lake)	Ventura	200	500
Calleguas and Conejo	Ventura	200	500
Bolsa Chica	Orange	2,500	500
Newport	Orange	500	None
Carlsbad Lagoon	San Diego	250	800
San Marcos Lagoon	San Diego	1,000	1,250
Escondido Creek Lagoon	San Diego	750	800
Mission Bay	San Diego		25
Tijuana River Lagoon	San Diego	500	250
TOTALS		141,884	321,825

APPENDIX G

HYDROELECTRIC POWER INSTALLATIONS IN CALIFORNIA

12—99801

TABLE OF CONTENTS

HYDROELECTRIC POWER INSTALLATIONS IN CALIFORNIA

Hydrographic area, and plant name	Owner	Stream	Installed power capacity, in kilowatts	Estimated average annual generation, in 1,000 kilowatt-hours	Estimated average annual water requirement, in acre-feet	Gross head, in feet
North Coastal Area						
Copco No. 1	California Oregon Power Co.	Klamath River	20,000	106,000	1,499,000	122
Copco No. 2	Same	Same	27,000	130,000	1,476,000	151
Fall Creek	Same	Fall Creek	2,200	10,000	27,000	730
Junction City	Pacific Gas & Electric Co.	Trinity River	2,720	10,200	10,500	602
Salyer	Swanson Mining Corp.	Same	1,600	170		
Potter Valley	Pacific Gas & Electric Co.	Russian River	8,800	58,000	183,300	476
TOTALS, NORTH COASTAL AREA			62,320	314,370		
South Coastal Area						
Franklin Canyon	Los Angeles Department of Water and Power	Los Angeles Aqueduct	2,000	8,800	52,300	285
San Francisquito No. 1	Same	Same	58,875	210,000	323,500	935
San Francisquito No. 2	Same	Same	42,000	115,000	319,900	540
San Fernando	Same	Same	5,600	50,000	264,300	250
Azusa	City of Pasadena	San Gabriel River	3,000	14,000	43,000	401
Sierra	Southern California Edison Co.	San Antonio Creek	480	4,000	14,100	628
Ontario No. 1	Same	Same	600	4,800	15,100	700
Ontario No. 2	Same	Same	320	1,100	10,900	276
Lytle Creek	Same	Lytle Creek	400	4,000	18,300	472
Fontana	Same	Same	1,920	8,800	36,000	658
Santa Ana No. 1	Same	Santa Ana River	2,400	18,000	42,800	726
Santa Ana No. 2	Same	Same	800	8,000	40,300	310
Santa Ana No. 3	Same	Same	1,200	7,000	37,500	354
Mill Creek No. 3	Same	Mill Creek	1,800	14,000	14,000	1,911
Mill Creek No. 2	Same	Same	200	1,500	5,000	620
Mill Creek No. 1	Same	Same	800	4,700	21,500	510
Rincon	Escondido Mutual Water Co.	San Luis Rey River	240	300	360	824
Bear Valley	Same	Escondido Creek	520	4,800	19,200	400
TOTALS, SOUTH COASTAL AREA			123,155	478,800		
Central Valley Area						
Sacramento River Basin						
Alturas	California Oregon Power Co.	Pine Creek	450	1,700		365
Pit No. 1	Pacific Gas & Electric Co.	Pit River	56,000	288,100	725,900	454
Pit No. 3	Same	Same	72,900	382,400	1,644,000	315
Pit No. 5	Same	Same	128,000	826,000	1,563,000	615
Hat Creek No. 1	Same	Hat Creek	10,000	45,000	203,400	217
Hat Creek No. 2	Same	Same	10,000	50,800	304,800	198
Shasta	U. S. Bureau of Reclamation	Sacramento River	379,000	1,863,000	5,696,000	480
Keswick	Same	Same	75,000	347,000	5,915,000	101
Kilarc	Pacific Gas & Electric Co.	North Fork Cow Creek	3,000	16,900	24,700	1,192
Cow Creek	Same	Cow Creek	1,200	11,700	26,500	715
Volta	Same	North Fork Battle Creek	6,400	45,800	57,300	1,254
South	Same	South Fork Battle Creek	4,000	35,600	94,600	516
Inskip	Same	Same	6,000	40,000	178,500	378
Coleman	Same	Battle Creek	13,800	57,500	195,800	482
De Sabla	Same	Big Butte Creek	13,000	83,200	81,000	1,531
Centerville	Same	Same	6,400	35,600	105,700	577
Hamilton Branch	Same	Hamilton Branch, Feather River	4,800	15,000	61,500	389
Caribou	Same	North Fork Feather River	60,000	451,000	562,000	1,150
Bucks Creek	Same	Same	66,000	198,000	132,300	2,558
Rock Creek	Same	Same	113,400	454,000	1,386,000	535
Cresta	Same	Same	67,500	298,000	1,766,000	290
Big Bend No. 1	Same	Same	52,000	454,000	1,297,000	465
Lime Saddle	Same	West Branch, North Fork Feather River	1,600	11,300	41,200	462
Coal Canyon	Same	Dry Creek	800	7,500	20,500	350
Sierra City	Same	North Fork Yuba River	30			
Bullards Bar	Same	Same	6,500	38,900	382,300	166
Colgate	Same	Same	24,000	154,000	261,300	810
Spaulding No. 3	Same	South Fork Yuba River	6,300	29,100	150,300	318
Spaulding No. 1	Same	Same	6,400	42,100	381,200	197
Spaulding No. 2	Same	Same	3,750	20,000	104,600	344
Narrows	Same	Yuba River	9,350	89,000	454,300	240
Deer Creek	Same	Deer Creek	5,500	31,300	59,200	837
Drum	Same	Bear River	44,000	282,500	296,200	1,375

HYDROELECTRIC POWER INSTALLATIONS IN CALIFORNIA—Continued

Hydrographic area and plant name	Owner	Stream	Installed power capacity, in kilowatts	Estimated average annual generation, in 1,000 kilowatt-hours	Estimated average annual water requirement, in acre-feet	Gross head, in feet
Sacramento River Basin—Continued						
Alta	Same	Same	2,000	6,400	12,200	66
Dutch Flat	Same	Same	22,000	147,000	30,000	643
Halsey	Same	Dry Creek	10,000	66,800	232,100	331
Wise	Same	Auburn Ravine	10,000	90,700	202,500	519
El Dorado	Same	South Fork American River	20,000	97,700	77,600	1,910
American River	Same	Same	5,750	30,000	14,600	573
Subtotals, Sacramento River Basin			1,326,830	7,144,600		
San Joaquin River Basin						
Big Creek No. 8	Southern California Edison Co.	San Joaquin River	54,000	309,200	548,600	713
Big Creek No. 3	Same	Same	106,500	743,500	1,252,000	827
Big Creek No. 4	Same	Same	84,000	490,000	1,305,000	418
Kerckhoff	Pacific Gas & Electric Co.	Same	34,080	275,400	966,300	350
Big Creek No. 1	Southern California Edison Co.	Big Creek	67,000	583,600	308,800	2,131
Big Creek No. 2	Same	Same	57,750	506,600	319,300	1,858
Big Creek No. 2A	Same	Same	80,000	238,500	237,200	2,418
Crane Valley	Pacific Gas & Electric Co.	North Fork San Joaquin River	800	2,700	80,300	90
San Joaquin No. 3	Same	Same	4,800	20,300	73,500	405
San Joaquin No. 2	Same	Same	2,400	11,000	78,000	307
San Joaquin No. 1A	Same	Same	340	1,300	54,300	43
A. G. Wishon	Same	Same	12,800	85,900	249,100	1,412
Yosemite	National Park Service	Merced River	2,000	11,000	40,200	336
Exchequer	Merced Irrigation District	Same	25,000	127,800	805,100	300
Merced	Pacific Gas & Electric Co.	Same	3,440	16,100	628,200	27
Early Intake	San Francisco Utilities Comm.	Cherry Creek	3,600	28,000	100,500	343
Moccasin Creek	Same	Moccasin Creek	70,000	508,000	519,000	1,316
Don Pedro	Turlock-Modesto Irrigation District	Tuolumne River	26,990	199,800	1,339,000	261
La Grange	Turlock-Modesto Irrigation District	Tuolumne River	3,900	25,200	125,900	117
Spring Gap	Pacific Gas & Electric Co.	Middle Fork, Stanislaus River	6,000	48,200	35,600	1,865
Phoenix	Same	South Fork, Stanislaus River	1,600	9,000	13,000	1,087
Murphys	Same	Angels Creek	3,800			
Angels	Same	Same	1,400	7,000	19,900	448
Stanislaus	Same	Same	28,900	233,500	238,600	1,499
Melones	Same	Same	24,300	95,300	618,200	230
Bear River	Same	North Fork, Mokelumne River	29,700	141,000		2,104
Salt Springs	Same	Same	9,350	42,800	380,300	255
Tiger Creek	Same	Same	51,000	353,000	336,500	1,219
West Point	Same	Same	13,600	91,400	414,800	312
New Electra	Same	Mokelumne River	89,100	363,500	442,400	1,268
Pardee	East Bay Municipal Utility District	Same	15,000	90,000	362,400	327
Subtotals, San Joaquin River Basin			913,150	5,658,600		
Tulare Lake Basin						
Kern River No. 3	Southern California Edison Company	Kern River	32,000	197,500	302,200	821
Borel	Same	Same	8,200	63,800	229,800	270
Kern River No. 1	Same	Same	16,000	173,200	224,100	877
Kern Canyon	Pacific Gas & Electric Co.	Same	8,480	59,600	326,700	262
Tule River	Same	Middle Fork, Tule River	4,800	24,500	24,700	1,532
Tule	Southern California Edison Co.	Tule River	2,000	17,000	22,800	1,140
Kaweah No. 3	Same	Kaweah River	2,800	24,700	55,800	775
Kaweah No. 1	Same	Same	2,250	14,000	18,800	1,326
Kaweah No. 2	Same	Same	1,800	11,000	44,700	367
Balch	Pacific Gas & Electric Co.	North Fork Kings River	31,000	178,600	102,600	2,336
Subtotals, Tulare Lake Basin			109,330	763,900		
TOTALS, CENTRAL VALLEY AREA			2,349,310	13,567,100		

HYDROELECTRIC POWER INSTALLATIONS IN CALIFORNIA—Continued

Hydrographic area and plant name	Owner	Stream	Installed power capacity, in kilowatts	Estimated average annual generation, in 1,000 kilowatt-hours	Estimated average annual water requirement, in acre-feet	Gross head, in feet
Lahontan Area						
Farad	Sierra Pacific Power Co.	Truckee River	2,800	17,000	290,000	83
Rush Creek	California Electric Power Co.	Rush Creek	8,400	44,000	32,300	1,807
Poole	Same	Leevining Creek	10,000	26,000	29,600	1,675
Mill Creek	Same	Mill Creek	2,400	8,100	21,700	785
Haiwee	Los Angeles Department of Water and Power	Los Angeles Aqueduct	5,600	34,000	320,900	193
Cottonwood	Same	Cottonwood Creek	1,500	5,800	6,110	1,267
Division Creek No. 2	Same	Division Creek	600	3,000	4,460	1,250
Big Pine No. 3	Same	Big Pine Creek	3,200	15,000	15,600	1,245
Upper Gorge	Same	Owens River	37,500	155,000	197,800	792
Middle Gorge	Same	Same	37,500	155,000	197,800	767
Central Gorge	Same	Same	37,500	158,000	197,800	781
Laws	Champion Sillimanite, Inc	Milner Creek	312	400		1,017
Bishop Creek No. 2	California Electric Power Co.	Bishop Creek	6,320	39,000	65,300	953
Bishop Creek No. 3	Same	Same	6,600	35,000	65,300	809
Bishop Creek No. 4	Same	Same	6,300	44,000	65,300	1,112
Bishop Creek No. 5	Same	Same	3,500	18,000	68,000	420
Bishop Creek No. 6	Same	Same	1,800	11,300	68,000	620
TOTALS, LAHONTAN AREA			171,832	768,600		
Colorado Desert Area						
San Gorgonio No. 1	California Electric Power Co.	San Gorgonio Creek	1,500	3,000	910	1,773
San Gorgonio No. 2	Same	Same	750	1,500	910	898
Siphon Drop	U. S. Bureau of Reclamation	Yuma Canal	1,600	15,000	1,436,000	15
Drop No. 3	Imperial Irrigation District	All-American Canal	4,800	45,000	2,100,000	25
Drop No. 4	Same	Same	19,600	100,000	2,600,000	50
Parker	U. S. Bureau of Reclamation	Colorado River	120,000	700,000	8,445,000	76
TOTALS, COLORADO DESERT AREA			148,250	864,500		
Colorado River Power Installations						
Hoover	U. S. Bureau of Reclamation	Colorado River	1,249,800	5,348,000		530
Davis	Same	Same	225,000	1,065,000		145

APPENDIX H

MAJOR RESERVOIRS OF CALIFORNIA

TABLE OF CONTENTS

MAJOR RESERVOIRS OF CALIFORNIA

Reservoir	Stream	Section	Township	Range	Base and meridian	Purpose	Crest elevation, in feet above mean sea level	Storage capacity, in acre-feet
North Coastal Area								
Clear Lake	Lost River	8	47N	8E	M.D.	Irrigation	4,552	527,000
Lake Pillsbury (Scott Dam)	South Eel River	14 and 23	18N	10W	M.D.	Power	1,920	93,724
Copco No. 1	Klamath River	29	48N	4W	M.D.	Power	2,613	77,000
Dwinnell (Shasta River Dam)	Shasta River	25	43N	5W	M.D.	Irrigation	2,828	33,000
Sweasey	Mad River	16	5N	2E	H.	Municipal	200	3,000
Earl B. Fiock No. 2	Tributary of Shasta River	6	44N	5W	M.D.	Irrigation	2,625	2,249
Janes Flat	Mosquito Creek	25	47N	10E	M.D.	Irrigation	5,100	1,400
Benbow	East Fork of South Fork Eel River	36	4S	3E	H.	Power	374	1,060
Earl B. Fiock	Tributary Little Shasta River	1	44N	6W	M.D.	Irrigation	2,525	1,000
"M"	Tributary Fairchild Meadow	13	44N	9E	M.D.	Irrigation	5,050	1,000
San Francisco Bay Area								
Calaveras	Calaveras Creek	13	5S	1E	M.D.	Municipal	775	100,000
Anderson	Coyote River	10	9S	3E	M.D.	Irrigation, municipal	640	75,000
Lower Crystal Springs	San Mateo Creek	1	5S	5W	M.D.	Municipal	289	54,000
San Pablo	San Pablo Creek	12	1N	4W	M.D.	Municipal	328	43,193
Upper San Leandro	San Leandro Creek	16 and 17	2S	2W	M.D.	Municipal	475	41,436
Lake Hennessey (Conn Creek Dam)	Conn Creek	1	7N	5W	M.D.	Municipal	330	30,000
Coyote	Coyote Creek	29	9S	4E	M.D.	Irrigation, municipal	803	27,770
Lexington	Los Gatos Creek	29	8S	1W	M.D.	Municipal, irrigation	665	25,000
San Andreas	San Andreas Creek	16	4S	5W	M.D.	Municipal	456	18,500
Kent Lake (Peters Dam)	Lagunitas Creek	23	2N	8W	M.D.	Municipal	368	16,500
Upper Crystal Springs	Laguna Creek	12	5S	5W	M.D.	Municipal	292	15,500
Lake Chabot (Lower San Leandro Dam)	San Leandro Creek	30	2S	2W	M.D.	Municipal	245	12,600
Lake Curry	Gordon Valley Creek	19	6N	2W	M.D.	Municipal	392	10,700
Calero	Calero Creek	6	9S	2E	M.D.	Irrigation, municipal	490	9,300
Alpine	Lagunitas Creek	16	1N	7W	M.D.	Municipal	654	9,210
Austrian	Los Gatos Creek	24	9S	1W	M.D.	Municipal	1,125	6,000
Novato Creek	Novato Creek	9	3N	7W	M.D.	Municipal	195	4,430
Rector Creek	Rector Creek	19	7N	4W	M.D.	Municipal, irrigation	380	4,400
Bon Tempe	Lagunitas Creek	11	1N	7W	M.D.	Municipal	724	4,000
Stevens Creek	Stevens Creek	27	7S	2W	M.D.	Irrigation, municipal	545	4,000
Guadalupe	Guadalupe Creek	32	8S	1E	M.D.	Irrigation, municipal	627	3,500
Lafayette	Lafayette Creek	36	1N	3W	M.D.	Municipal	466	3,500
Mallard	Tributary Suisun Bay	13	2N	2W	M.D.	Municipal	36	3,113
Pilarcitos	Pilarcitos Creek	33	4S	5W	M.D.	Municipal	700	3,100
Lake Herman	Sulphur Springs Valley Creek	24	3N	3W	M.D.	Municipal	122	2,210
Almaden	Almaden Creek	11	9S	1E	M.D.	Irrigation, municipal	615	2,000
Milliken	Milliken Creek	7	6N	3W	M.D.	Municipal	923	2,000
Lake Madigan	Wild Horse Valley Creek	4	5N	3W	M.D.	Municipal	1,383	1,744
Lake Chabot	Sulphur Springs Creek	6	3N	3W	M.D.	Municipal	85	1,430
Lake Frey	Wild Horse Valley Creek	9	5N	3W	M.D.	Municipal	1,207	1,075
Central Coastal Area								
Cachuma	Santa Ynez River	24	6N	30W	S.B	Irrigation, municipal	776	210,000
Salinas	Salinas River	8	30S	14E	M.D.	Municipal	1,320	26,000
Santa Barbara (Gibraltar Dam)	Santa Ynez River	14	5N	27W	S.B.	Municipal	1,402	15,000
Elmer J. Chesbro	Llagas Creek	30	9S	3E	M.D.	Irrigation, municipal	535	7,500
Jameson Lake (Juncal Dam)	Santa Ynez River	28	5N	25W	S.B.	Municipal, irrigation	2,230	7,064
North Fork	Pacheco Creek	22	10S	6E	M.D.	Irrigation	483	6,150
Paicines	Tributary Tres Pinos Creek	11	14S	6E	M.D.	Irrigation	701	4,500
Los Padres	Carmel River	8	18S	3E	M.D.	Municipal	1,053	3,000
San Clemente	Carmel River	24	17S	2E	M.D.	Municipal	535	2,154
South Coastal Area								
Prado	Santa Ana River	20	3S	7W	S.B.	Flood control	566	223,000
Henshaw	San Luis Rey River	10	11S	2E	S.B.	Irrigation	2,740	203,581
El Capitan	San Diego River	7	15S	2E	S.B.	Municipal	770	118,000
Santa Felicia	Piru Creek	----	4N	18W	S.B.	Irrigation, power, municipal	1,075	100,000
Lake Mathews	Tributary Cajalco Creek	12	4S	6W	S.B.	Municipal	1,371	100,000
San Vincente	San Vincente Creek	31	14S	1E	S.B.	Municipal	650	90,231
Big Bear Lake (Bear Valley Dam)	Bear Creek	22	2N	1W	S.B.	Irrigation	6,746	72,400
Morena	Cottonwood Creek	14	17S	4E	S.B.	Municipal	3,049	53,700
Vail	Temecula Creek	10	8S	1W	S.B.	Irrigation	1,479	51,000
Lower Otay (Savage Dam)	Otay River	18	18S	1E	S.B.	Municipal	492	49,126
San Gabriel No. 1	San Gabriel River	6	1N	9W	S.B.	Flood control	1,481	43,825
Barrett	Cottonwood Creek	22	17S	3E	S.B.	Municipal	1,617	42,899
Bouquet Canyon	Bouquet Creek	29	6N	14W	S.B.	Municipal	3,008	36,200
Hansen	Big Tujunga Creek	18	2N	14W	S.B.	Flood control	1,087	35,800
Morris	San Gabriel River	13	1N	10W	S.B.	Municipal	1,175	35,171
Whittier Narrows	San Gabriel River and Rio Hondo	1, 4, 5, and 6	2S 2S	12W 11W	S.B. S.B.	Flood control	239	35,000
Lake Hodges	San Dieguito River	18	13S	2W	S.B.	Municipal	330	33,482

MAJOR RESERVOIRS OF CALIFORNIA—Continued

Reservoir	Stream	Section	Township	Range	Base and meridian	Purpose	Crest elevation, in feet above mean sea level	Storage capacity, in acre-feet
South Coastal Area—Continued								
Santa Fe	San Gabriel River	6	1S	10W	S.B.	Flood control	514	33,000
Sutherland	Santa Ysabel Creek	21	12S	2E	S.B.	Municipal	2,074	29,000
Lake Loveland	Sweetwater River	17	16S	2E	S.B.	Municipal	1,368	27,700
Sweetwater	Sweetwater River	17	17S	1W	S.B.	Municipal	240	27,689
Santiago Creek	Santiago Creek	33	4S	8W	S.B.	Irrigation	810	25,000
Lower San Fernando	San Fernando Creek	5	2N	15W	S.B.	Municipal	1,142	18,900
Sepulveda	Los Angeles River	17	1N	15W	S.B.	Flood control	725	17,400
Puddingstone	Walnut Creek	15	1S	9W	S.B.	Flood control	982	17,190
Railroad Canyon	San Jacinto River	2	6S	4W	S.B.	Irrigation	1,390	15,200
Lake Hemet	South Fork San Jacinto River	7	6S	3E	S.B.	Irrigation	4,336	14,000
Cuyamaca	Boulder Creek	5	14S	4E	S.B.	Irrigation, municipal	4,641	11,600
Cogswell	West Fork San Gabriel River	19	2N	10W	S.B.	Flood control	2,405	10,915
Chatsworth	Tributary Los Angeles River	25	2N	17W	S.B.	Municipal	898	10,500
Stone Canyon	Stone Canyon Creek	9	1S	15W	S.B.	Municipal	856	7,960
Lake Wohlford	Escondido Creek	5	12S	1W	S.B.	Municipal, irrigation	1,479	7,500
Matilija	Matilija Creek	29	5N	23W	S.B.	Flood control	1,138	7,000
Murray	Chapparel Canyon	13	16S	2W	S.B.	Municipal	540	5,885
Pacoima	Pacoima Creek	19	3N	14W	S.B.	Flood control	2,015	4,714
San Joaquin Flood Control	Tributary Newport Bay	18	6S	9W	S.B.	Flood control	30	4,500
Big Tujunga No. 1	Big Tujunga Creek	1	2N	13W	S.B.	Flood control	2,304	4,236
Brea	Brea Creek	21	3S	10W	S.B.	Flood control	295	4,090
Hollywood (Mulholland Dam)	Weid Canyon	3	1S	14W	S.B.	Municipal	756	4,034
Encino	Encino Creek	24	1N	16W	S.B.	Municipal	1,022	3,230
Upper Otay	Procter Valley Creek	36	17S	1W	S.B.	Municipal	555	2,793
Lake Sherwood	Triunfo Creek	27	1N	19W	S.B.	Recreation, irrigation	954	2,694
Devils Gate	Arroyo Seco	7	1N	12W	S.B.	Flood control	1,070	2,504
Silver Lake	Tributary Balona Creek	8	1S	13W	S.B.	Municipal	458	2,162
Yorba	Tributary Santa Ana River	34	3S	9W	S.B.	Municipal	290	2,000
Upper San Fernando	San Fernando Creek	31	3N	15W	S.B.	Municipal	1,219	1,640
Dry Canyon	Dry Canyon Creek	35	5N	16W	S.B.	Municipal	1,514	1,325
Sycamore	Sycamore Canyon	31	2S	4W	S.B.	Flood control	1,013	1,150
San Dieguito	Tributary Escondido Creek	16	13S	3W	S.B.	Municipal	250	1,128
Lee Lake	Temescal Creek	7	5S	5W	S.B.	Irrigation	1,153	1,100
Palos Verdes	Tributary Los Angeles Harbor	33	4S	14W	S.B.	Municipal	330	1,100
Peters Canyon	Peters Canyon	31	4S	8W	S.B.	Irrigation	538	1,090
Lower Franklin	Franklin Canyon	12	1S	15W	S.B.	Municipal	586	1,052
San Dimas	San Dimas Creek	24	1N	9W	S.B.	Flood control	1,470	1,042
Mocking Bird	Mockingbird Canyon	21	3S	5W	S.B.	Irrigation	1,010	1,000
Central Valley Area								
Shasta	Sacramento River	15	33N	5W	M.D.	Power, irrigation	1,078	4,492,000
Monticello	Putah Creek	29	8N	2W	M.D.	Irrigation, flood control	456	1,600,000
Lake Almanor	North Fork Feather River	28	27N	8E	M.D.	Power	4,515	1,308,000
Pine Flat	Kings River	2	13S	24E	M.D.	Irrigation, flood control	970	1,000,000
Folsom	American River	24	10N	7E	M.D.	Flood control, irrigation, power, municipal	480	1,000,000
Isabella	Kern River	19	26S	32E	M.D.	Flood control, irrigation	2,634	550,000
Millerton Lake (Friant Dam)	San Joaquin River	5	11S	21E	M.D.	Flood control, irrigation	582	520,500
Clear Lake	Cache Creek	6	12N	6W	M.D.	Irrigation	1,328	420,000
Hetch Hetchy (O'Shaughnessy Dam)	Tuolumne River	16	1N	20E	M.D.	Municipal, power	3,812	360,000
Lake McClure (Exchequer Dam)	Merced River	13	4S	15E	M.D.	Irrigation, power	710	289,000
Don Pedro	Tuolumne River	35	2S	14E	M.D.	Irrigation, power	609	289,000
Cherry Valley	Cherry River	5	1N	19E	M.D.	Municipal, flood control, power	4,715	268,000
Pardee	Mokelumne River	26	5N	10E	M.D.	Municipal, power	575	210,000
Buena Vista Lake	Kern River	32	30S	25E	M.D.	Irrigation	300	205,000
Salt Springs	North Fork Mokelumne River	33	8N	16E	M.D.	Power	3,960	139,400
Shaver Lake	Stevenson Creek	13	9S	24E	M.D.	Power	5,371	135,283
Wishon	North Fork Kings River	6	11S	28E	M.D.	Power	6,550	128,000
Vermillion Valley	Mono Creek	25 and 26	6S	27E	M.D.	Power	7,650	125,000
Melones	Stanislaus River	11	1N	13E	M.D.	Irrigation, power	723	112,500
Bucks Creek	Bucks Creek	33	24N	7E	M.D.	Power	5,168	103,000
Beardsley	Middle Fork Stanislaus River	14 and 15	4N	17E	M.D.	Irrigation, power	3,405	97,500
Huntington Lake	Big Creek	14	8S	25E	M.D.	Power	6,954	88,834
Big Sage	Rattlesnake Creek	7	43N	12E	M.D.	Irrigation	4,907	77,000
Hogan	Calaveras River	31	4N	11E	M.D.	Flood control	654	76,000
Lake Spaulding	South Fork Yuba River	20	17N	12E	M.D.	Power, irrigation, municipal	5,014	74,488
Englebright (Upper Narrows)	Yuba River	14	16N	6E	M.D.	Debris, power	542	70,000
Tulloch	Stanislaus River	1	1S	12E	M.D.	Irrigation, power	515	68,400
Bowman Lake	Canyon Creek	5	18N	12E	M.D.	Irrigation, power	5,567	68,000

MAJOR RESERVOIRS OF CALIFORNIA—Continued

Reservoir	Stream	Section	Township	Range	Base and meridian	Purpose	Crest elevation, in feet above mean sea level	Storage capacity, in acre-feet
Central Valley Area—(Continued)								
Donnell	Middle Fork Stanislaus River	35	6N	18E	M.D.	Irrigation, power	4,917	64,500
Florence Lake	South Fork San Joaquin River	36	7S	27E	M.D.	Power	7,329	64,406
Farmington	Littlejohns Creek	25	1N	9E	M.D.	Flood control	174	52,000
East Park	Little Stony Creek	3	17N	6W	M.D.	Irrigation	1,202	51,000
Stony Gorge	Stony Creek	16	20N	6W	M.D.	Irrigation	847	50,200
Butt Valley	Butt Creek	13	26N	7E	M.D.	Power	4,144	49,768
Owen	Tributary Tuolumne River	31	3S	13E	M.D.	Irrigation	233	49,000
Lower Bear River	Bear River	18	8N	16E	M.D.	Power	5,820	48,500
Lake Fordyce	Fordyce Creek	34	18N	13E	M.D.	Power, irrigation, municipal	6,481	46,662
Bass Lake (Crane Valley Dam)	North Fork San Joaquin River	25	7S	22E	M.D.	Power	3,380	45,410
Sly Park	Sly Park Creek	17 and 18	10N	13E	M.D.	Irrigation	3,482	41,000
Lake Britton (Pit River No. 3 Dam)	Pit River	30	37N	3E	M.D.	Power	2,770	40,600
Tule Lake	Cedar Creek	33	38N	14E	M.D.	Irrigation, preservation of wild fowl	5,524	39,500
Woodward	Simmons Creek	9	1S	10E	M.D.	Irrigation	215	35,000
Big Creek No. 7	San Joaquin River	15	9S	23E	M.D.	Power	1,414	35,000
Bullards Bar	North Fork Yuba River	24	18N	7E	M.D.	Power	1,590	31,489
Lake Eleanor	Eleanor Creek	3	1N	19E	M.D.	Power, municipal	4,661	27,800
Dallas-Warner	Tributary Tuolumne River	20	3S	12E	M.D.	Irrigation	215	27,000
Scotts Flat	Deer Creek	11	16N	9E	M.D.	Irrigation, municipal	3,050	26,300
Mountain Meadows (Indian 'Ole Dam)	Hamilton Creek	13	28N	8E	M.D.	Power	4,962	24,800
Keswick	Sacramento River	21	32N	5W	M.D.	Irrigation, power	596	24,000
Twin Lake	Silver Fork of South Fork American River	18	10N	18E	M.D.	Power	7,960	21,250
Strawberry	South Fork Stanislaus River	15	4N	18E	M.D.	Power, irrigation, municipal	5,620	18,600
West Valley	West Valley Creek	18	39N	14E	M.D.	Irrigation	4,775	17,700
Relief	Relief Creek	13	5N	20E	M.D.	Power	7,340	15,122
Mariposa	Mariposa Creek	30	7S	17E	M.D.	Flood control	456	15,000
Big Dry Creek	Big Dry Creek	22	12S	21E	M.D.	Flood control	435	15,000
North Fork	North Fork American River	31	13N	9E	M.D.	Debris	718	14,600
French Lake	Canyon Creek	17	18N	13E	M.D.	Irrigation, power	6,664	12,500
Dorris	Stockdill Slough	8 and 17	42N	13E	M.D.	Irrigation	4,360	11,100
Salt Springs Valley	Rock Creek	16	2N	11E	M.D.	Irrigation	1,178	10,900
Lake Combie	Bear River	2	13N	8E	M.D.	Irrigation	1,610	9,000
Silver Lake	Silver Fork of South Fork American River	32	10N	17E	M.D.	Power	7,209	8,726
Lake Wilenor	Concow Creek	16	22N	4E	M.D.	Irrigation	1,970	8,600
Lake Valley	North Fork of North Fork American River	35	17N	12E	M.D.	Power	5,853	8,127
Loon Lake	Gerle Creek	4 and 5	13N	15E	M.D.	Irrigation, municipal	6,500	8,000
Nimbus	American River	16	9N	7E	M.D.	Irrigation, municipal, power	132	7,700
Upper Blue Lake	Blue Creek	18	9N	19E	M.D.	Power	8,131	7,500
Burns	Burns Creek	25	6S	15E	M.D.	Flood control	320	7,000
Lake Yosemite	Fahrens Creek	33	6S	14E	M.D.	Irrigation	255	7,000
Bear River	Bear River	9	8N	16E	M.D.	Power	5,882	6,756
North Big Dobe	Tributary Rattlesnake Creek	22	44N	12E	M.D.	Irrigation	5,000	6,530
Lake Van Norden	South Fork Yuba River	23	17N	14E	M.D.	Power	6,770	5,874
Meadow Lake	Tributary North Fork Mokelumne River	27	9N	18E	M.D.	Power	7,773	5,850
Bucks Diversion	Bucks Creek	29	24N	7E	M.D.	Power	5,029	5,843
Lyons	South Fork Stanislaus River	24	3N	16E	M.D.	Irrigation, power, municipal	4,226	5,508
Medley Lakes	Pyramid Creek	30	12N	17E	M.D.	Power	8,210	5,350
Coyote Flat	Coyote Creek	31	36N	9E	M.D.	Irrigation	4,807	5,250
Lost Creek	Lost Creek	24	20N	7E	M.D.	Irrigation	3,112	5,200
Camp Far West	Bear River	21	14N	6E	M.D.	Irrigation	198	5,000
Philbrook	Philbrook Creek	13	25N	4E	M.D.	Irrigation, power	5,424	4,875
Round Valley	North Canyon Creek	15	26N	9E	M.D.	Irrigation	4,470	4,800
Meadow Lake	Tributary Fordyce Creek	27	18N	13E	M.D.	Power	7,252	4,800
Misselbeck	North Fork Cottonwood Creek	31	31N	7W	M.D.	Irrigation	2,200	4,800
Rock Creek	North Fork Feather River	26 and 35	25N	6E	M.D.	Power	2,220	4,660
Silver Valley	Tributary North Fork Stanislaus River	9	7N	18E	M.D.	Power	7,304	4,600
Cresta	North Fork Feather River	2	23N	5E	M.D.	Power	1,680	4,400
Kerckhoff Diversion	San Joaquin River	24	9S	22E	M.D.	Power	994	4,300
Lower Blue Lake	Blue Creek	30	9N	19E	M.D.	Power	8,040	4,300
Essex (S-X)	Tributary Pit River	6	42N	11E	M.D.	Irrigation	4,600	4,225
Tiger Creek Afterbay	North Fork Mokelumne River	23	7N	13E	M.D.	Power	2,340	3,960
Silva Flat	Juniper Creek	10	36N	9E	M.D.	Irrigation	5,400	3,900
South Big Dobe	Tributary Rattlesnake Creek	26	44N	12E	M.D.	Irrigation	5,000	3,860
Spicers Meadows	Highland Creek	3	6N	18E	M.D.	Power	6,421	3,800
Owens Creek	Owens Creek	23	7S	16E	M.D.	Flood control	422	3,600
Magalia	Little Butte Creek	25	23N	3E	M.D.	Irrigation, municipal	2,234	3,540

MAJOR RESERVOIRS OF CALIFORNIA—Continued

Reservoir	Stream	Section	Township	Range	Base and meridian	Purpose	Crest elevation, in feet above mean sea level	Storage capacity, in acre-feet
Central Valley Area (Continued)								
Spooner	Tributary Ash Creek	30	37N	12E	M.D.	Irrigation	5,500	3,123
Sawmill Lake	Canyon Creek	11	18N	12E	M.D.	Irrigation, power	5,780	3,040
Wallace	Tributary Mokelumne River	15	4N	9E	M.D.	Mining	300	3,000
Mendota Diversion	San Joaquin River	19	13S	15E	M.D.	Irrigation	168	3,000
Sequoia Lake	Mill Flat Creek	1	14S	27E	M.D.	Recreation	5,400	3,000
Payne	Tributary South Fork Pit River	15	41N	13E	M.D.	Irrigation	5,000	2,850
Pit No. 1 Forebay	Fall River	25	37N	4E	M.D.	Power	3,330	2,800
Duncan	Tributary Pit River	33	43N	9E	M.D.	Irrigation	4,900	2,575
Lodi Lake (Woodbridge Diversion and Dam)	Mokelumne River	34 and 35	4N	6E	M.D.	Irrigation	48	2,464
Utica	North Fork Stanislaus River	21	7N	18E	M.D.	Power	6,775	2,400
Priest	Rattlesnake Creek	31	1S	16E	M.D.	Municipal, power	2,254	2,350
Big (Morning Star Dam)	Shirttail Canyon	17	15N	11E	M.D.	Domestic	4,100	2,200
Pit No. 4	Pit River	8	36N	2E	M.D.	Power	2,458	2,000
Union	North Fork Stanislaus River	28	7N	18E	M.D.	Power	6,852	2,000
Sutter Butte Diversion	Feather River	33	19N	3E	M.D.	Irrigation	120	2,000
Lake Francis	Dobbins Creek	5	17N	7E	M.D.	Power	1,650	1,905
Los Verjels	Dry Creek	34	18N	6E	M.D.	Irrigation	1,355	1,830
Schaad (Middle Fork Dam)	Middle Fork Mokelumne River	9	6N	14E	M.D.	Municipal	3,035	1,718
Detert Lake	Bucksnort Creek	9	10N	6W	M.D.	Irrigation	1,082	1,700
Everly	Bean Flat	26	47N	12E	M.D.	Irrigation	5,000	1,700
Lake Sterling	Sterling Creek	10	17N	13E	M.D.	Power	6,700	1,648
Upper Peak Lake	Tributary South Fork Yuba River	32	17N	14E	M.D.	Power	6,611	1,607
Antelope (Huffman)	Clover Swale	11	43N	10E	M.D.	Irrigation	4,800	1,550
Taylor Creek No. 1	Taylor Creek	8	39N	7E	M.D.	Irrigation	4,200	1,500
Kidd Lake	Tributary South Fork Yuba River	29	17N	14E	M.D.	Power	6,772	1,492
Emigrant Lake	North Fork Cherry Creek	30	4N	21E	M.D.	Recreation	8,800	1,491
Long Lake	Gray Eagle Creek	6	21N	12E	M.D.	Industrial	6,531	1,478
Antelope "C"	Antelope Plains	13	44N	10E	M.D.	Irrigation	5,000	1,450
Upper Sardine Lake	Tributary Yuba River	9	20N	12E	M.D.	Recreation	6,048	1,435
Hume Lake	Ten Mile Creek	4	13S	28E	M.D.	Recreation	5,300	1,410
Lower Empire Weir	South Fork Kings River	20	20S	20E	M.D.	Irrigation	203	1,400
Deer Creek Diversion	Deer Creek	10	16N	9E	M.D.	Irrigation	2,902	1,400
Davis No. 2	Tributary of Calaveras River	6	2N	9E	M.D.	Irrigation	144	1,400
Little Juniper	Little Juniper Creek	4	40N	13E	M.D.	Irrigation	4,800	1,370
Lake Wyandotte	North Fork Honcut Creek	16	19N	5E	M.D.	Irrigation	1,388	1,300
Twin Lakes	Tributary North Fork Mokelumne River	25	9N	18E	M.D.	Power	8,172	1,300
Round Valley	West Branch North Fork Feather River	30	26N	5E	M.D.	Power	5,498	1,285
Webber Creek	Webber Creek	18	10N	12E	M.D.	Irrigation	2,275	1,275
Davis Creek Orchards	Ewing Creek	30	45N	14E	M.D.	Irrigation	4,800	1,200
Lake Tabeaud	Jackson Creek	28	6N	12E	M.D.	Municipal, power	1,968	1,165
Pit No. 5 Open Conduit Embankment	Sugar Pine Creek	5	36N	1E	M.D.	Power	2,046	1,147
Fuller Lake	Jordan Creek	17	17N	12E	M.D.	Power	5,379	1,130
Blue Lake	Tributary Rucker Creek	9	17N	12E	M.D.	Power	5,964	1,123
Toreson	Tom's Creek	16	41N	10E	M.D.	Irrigation	4,850	1,118
Grizzly Creek Forebay	Grizzly Creek	34	24N	6E	M.D.	Power	4,321	1,112
Barron No. 1	Ash Creek	13 and 14	37N	11E	M.D.	Irrigation	5,222	1,061
North Battle Creek	North Fork Battle Creek	20	32N	3E	M.D.	Power	5,246	1,016
Kelsey	Tributary South Fork Dry Creek	31	4S	15E	M.D.	Irrigation	390	1,000
Nelson	Dry Creek	24	38N	12E	M.D.	Irrigation	5,400	1,000
McBrien	Pit River	27	42N	11E	M.D.	Irrigation	4,600	1,000
Jackson Lake	Jackson Creek	31	19N	13E	M.D.	Irrigation, power	6,600	1,000
Lahontan Area								
Lake Tahoe	Truckee River	6	15N	17E	M.D.	Irrigation, power	6,233	732,000
Lake Crowley (Long Valley Dam)	Owens River	19	4S	30E	M.D.	Municipal, power	6,796	183,743
Haiwee	Rose Valley	2	21S	37E	M.D.	Municipal, power	3,774	60,000
Grant Lake	Rush Creek	15	1S	26E	M.D.	Municipal, power	7,145	47,500
Lake Arrowhead	Little Bear Creek	14	2N	3W	S.B.	Recreation	5,116	47,000
Bridgeport	East Walker River	34	6N	25E	M.D.	Irrigation	6,469	42,455
Boca	Little Truckee River	28	18N	17E	M.D.	Irrigation	5,612	41,200
Independence	Independence Creek	35	19N	15E	M.D.	Power	6,952	18,500
Gem Lake	Rush Creek	30	2S	26E	M.D.	Power	9,053	17,604
McCoy Flat	Susan River	23	30N	9E	M.D.	Irrigation	5,542	17,290
Tinemaha	Owens River	25	10S	34E	M.D.	Municipal, power	3,882	16,605
South Lake (Hillside Dam)	South Fork Bishop Creek	15	9S	31E	M.D.	Power	9,708	13,368
Lake Leavitt	Tributary Susan River	15	29N	13E	M.D.	Irrigation	4,100	12,100
Saddlebag Lake	Leevining Creek	6	1N	25E	M.D.	Power	10,093	11,138
Donner Lake	Donner Creek	18	17N	16E	M.D.	Power, irrigation	5,937	11,000
Red Rock No. 1	Red Rock Creek	22	36N	16E	M.D.	Irrigation	5,600	9,560
Hog Flat	Tributary Susan River	25	30N	9E	M.D.	Irrigation	5,500	8,000
Fairmont	Antelope Valley	12	7N	15W	S.B.	Municipal, power	3,043	7,487
Sabrina	Middle Fork Bishop Creek	31	8S	31E	M.D.	Power	9,089	7,350
Harold	Tributary Antelope Valley	2 and 3	5N	12W	S.B.	Irrigation	2,826	6,575
Fallen Leaf Lake	Taylor Creek	2	12N	17E	M.D.	Recreation	6,382	6,400
Round Valley	Round Valley Creek	30	31N	12E	M.D.	Irrigation	5,000	5,000
Rush Creek Meadows	Rush Creek	14	2S	25E	M.D.	Power	9,413	4,970

MAJOR RESERVOIRS OF CALIFORNIA—Continued

Reservoir	Stream	Section	Township	Range	Base and meridian	Purpose	Crest elevation, in feet above mean sea level	Storage capacity, in acre-feet
Lahonton Area—Continued								
Littlerock	Littlerock Creek	27	5N	11W	S.B.	Irrigation	3,264	4,300
Pleasant Valley	Owens River	24	6S	31E	M.D.	Municipal	4,409	3,825
Lundy Lake	Mill Creek	16	2N	25E	M.D.	Power	7,808	3,820
Poison Springs	Rock Creek	33	46N	17E	M.D.	Irrigation	5,200	3,750
Cramer	Tributary Horse Lake	9	32N	13E	M.D.	Irrigation	5,063	3,000
Heenan Lake	Heenan Creek	3	9N	21E	M.D.	Irrigation	7,200	3,000
Lake Gregory	Huston Creek	23	2N	4W	S.B.	Municipal	4,530	2,300
Willow Creek	Willow Creek	5	30N	13E	M.D.	Irrigation	----	2,200
Red Rock No. 3	Tributary Red Rock Creek	4	35N	16E	M.D.	Irrigation	5,400	2,100
Lower Twin Lake	Robinson Creek	33	4N	24E	M.D.	Irrigation	7,079	2,000
Buckhorn	Buckhorn Creek	31	35N	17E	M.D.	Irrigation	5,950	2,000
Echo Lake	Tributary Upper Truckee River	1	11N	17E	M.D.	Power	7,460	1,900
Upper Twin Lake	Robinson Creek	5	3N	24E	M.D.	Irrigation	7,100	1,500
Antelope	Madeline Plains	3	34N	13E	M.D.	Irrigation	5,300	1,500
Tioga Lake	Tributary Leevining Creek	19	1N	25E	M.D.	Power	9,657	1,386
Branham Flat	Branham Creek	9	33N	13E	M.D.	Irrigation	5,600	1,200
Poore Lake	Poore Creek	2	5N	22E	M.D.	Irrigation	7,361	1,200
Big Pine Creek No. 2	Big Pine Creek	33	9S	32E	M.D.	Power	10,036	1,071
Colorado Desert Area								
Parker	Colorado River	3	2N	27E	S.B.	Municipal, power	455	717,000
Imperial	Colorado River	9	15S	24E	S.B.	Irrigation, power	197	85,000
Copper Basin	Copper Basin	11	2N	26E	S.B.	Municipal	1,038	22,000
Gene Wash	Gene Wash	32	3N	27E	S.B.	Municipal	746	6,300

M. D.—Mount Diablo Base and Meridian.
H.—Humboldt Base and Meridian.
S. B.—San Bernardino Base and Meridian.

APPENDIX I

WATER QUALITY CONSIDERATIONS AFFECTING USE OF THE WATERS OF CALIFORNIA

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WATER QUALITY CONSIDERATIONS AFFECTING USE OF THE WATERS OF CALIFORNIA

TABLES

WATER QUALITY CONSIDERATIONS AFFECTING USE OF THE WATERS OF CALIFORNIA

Unprecedented demands for water by a rapidly growing population and by expanding agricultural and industrial activities, coupled with the impact of recurrent drought, require the thorough consideration of problems of water quality in developing plans for future utilization of the waters of California. Increasing upstream uses of water impose the concomitant requirement that adequate facilities for treatment, disposal, or diversion of municipal, industrial, or agricultural waste waters be provided in order that the quality of water supplies for downstream uses is not adversely affected.

General aspects of the quality of water problem in California, particularly as it relates to water requirements, are presented in the following discussion.

DEFINITIONS

The terms "standards", "criteria", and "objectives", as applied to water quality, are often used interchangeably as synonyms. In reality they have distinct meanings. In order to provide a consistent basis for expression of ideas, the following definitions are used by the Division of Water Resources: *Standards* are official limits of quality for beneficial uses established by regulation or statute. *Criteria* are unofficial but recognized values or limits of quality for beneficial uses based on experience and research. *Objectives* are desired limits of quality for specific waters based on the beneficial uses of the water, use for waste disposal, legal standards, research criteria, common experience, and physical, political, and economic considerations. Compliance with water quality standards, criteria, or objectives is measured by test or analysis of representative water samples.

STANDARDS AND CRITERIA OF WATER QUALITY

Certain criteria or standards have been developed which are generally accepted as useful guides in determining whether water is of suitable quality for various beneficial uses. The quality criteria given in the following pages are for purposes of reference and comparison only. It should not be inferred that they are mandatory except in certain cases, as described in the text, where they have been adopted by regulation or statute.

Tests of Water Quality

The more common tests to determine the quality characteristics of representative samples of natural or waste waters are included in the following groups:

Mineral. A complete mineral analysis includes the determination of all of the mineral or inorganic constituents of water. As the term is generally used, mineral analysis signifies determination of those major constituents which are generally present in natural waters in significant quantity, including calcium, magnesium, sodium, potassium, carbonate, bicarbonate, sulfate, chloride, nitrate, boron, silica, fluoride, and hardness. The pH and the specific electrical conductance, generally reported in micromhos at 25° C., are also determined at the time of the analysis. A partial analysis, including limited mineral determinations, is made when the requirements of a particular investigation will be satisfied thereby, and when the number of samples is too great to permit more comprehensive analyses.

Physical. A physical analysis includes determination of the physical properties of water, such as temperature, color, turbidity, odor, and electrical conductance.

Sanitary. A sanitary chemical and biochemical analysis comprises the determination of certain substances and characteristics of sanitary significance. It may include dissolved oxygen, biochemical oxygen demand, oxygen consumed from chromic acid, nitrogen in its various forms, such as nitrate, ammonia, albuminoid, and total organic constituents, ether-soluble matter, such as fats, grease, etc., settleable solids, and total and suspended solids and ignition losses. Sanitary surveys consisting of investigation and evaluation of field conditions are required for accurate interpretation of the sanitary analysis.

Bacterial. A bacteriological examination comprises tests for presence of coliform organisms, which are used as an indicator of the sanitary quality of water for human consumption. Certain organisms of the coliform group are normal inhabitants of the intestines of man and other vertebrates, and therefore the presence of such organisms is considered presumptive evidence of contact of water supplies with human sewage. Results of the bacteriological examination are usually expressed in terms of the concentration of organisms in a given volume of sample. Concentrations are determined by statistical analysis of results of the tests and are reported as the Most Probable Number of coliform organisms.

Biological. The value of biological examination in appraising water quality has long been recognized, but the degree of scientific knowledge and skills required has often prevented its use. It comprises the collection, examination, identification, and quantitative measurement of aquatic organisms present in a body of water and on the stream bottom, and appraisal of their significance. Both visible (macroscopic) and invisible (microscopic) life forms are sought. The biological examination may serve any of the following purposes important to the water supply engineer: (1) to explain the causes of undesirable color, turbidity, odor, and taste in water, and to indicate methods for their removal; (2) to aid in interpreting other types of water analysis; (3) in special cases, to identify a source of water; (4) to identify organisms causing clogging of pipe lines and filters; (5) to indicate pollution by sewage and industrial wastes; and (6) to indicate progress of self-purification in natural surface waters.

Biological examination of water offers at least two important advantages as compared to ordinary methods of chemical analysis. First, it is to a large extent integrating with respect to time; that is to say, the distribution and condition of aquatic organisms reflect water quality conditions for a considerable period in the past. In contrast, the usual random or "grab" method of sampling employed for chemical analysis of water indicates water quality only at the instant of sampling, and often gives an untrue or abnormal impression of water quality. Secondly, aquatic organisms are often sensitive to toxic constituents which are not revealed in ordinary chemical analysis. Biological examinations are therefore a very useful supplement to chemical methods.

Quality Standards and Criteria for Various Water Uses

The suitability of a water supply for a specific use may be ascertained by comparison of its determined quality characteristics with the accepted quality criteria for the use under consideration. Values used to define suitability or acceptability of water for various beneficial uses are based upon the best information currently available. These values are general approximations but serve as a guide to judgment of suitability for the use under consideration. With respect to criteria, which, as heretofore stated, are not mandatory, the particular circumstances of each individual case must be assessed before a final determination of the suitability of a particular water supply can properly be made.

In applying quality criteria to water for a particular use, the rule of reasonableness should be considered. For example, it might be unreasonable to expect that the quality of the source water of an industrial water supply be maintained such that no treatment is required prior to use. Industries which have particularly exacting quality requirements ordinarily accept the necessity for special treatment of water at their own expense. In general, the responsibility of a public agency supplying industrial water is considered to be met if such water is of potable quality.

Drinking Water. No domestic water may be purveyed publicly in California without a permit from the State Board of Public Health. Such water supplies shall at all times be pure, wholesome, and potable.

Requirements have been promulgated by the United States Public Health Service governing the quality of waters used on interstate carriers. These standards have been incorporated by reference in the California Health and Safety Code. According to these standards, the chemical substances contained in drinking water supplies, either natural or treated, should not exceed the concentrations shown in Table I-1. Standards which are starred are mandatory, while the remainder are merely recommended as a desired objective. This table of constituents is by no means complete. Other mineral compounds may be included if their presence renders the water hazardous for safe use. As an example, in a letter to the Central Valley Regional Water Pollution Control Board, concerning the McClellan Air Force Base industrial waste discharge, the California Department of Public Health, Bureau of Sanitary Engineering, recommended that the safe limit for nickel in the receiving water at the water supply intake of the City of Sacramento be limited to one part per million.

Bacteriological requirements of the United States Public Health Service for drinking water are quoted as follows:

TABLE I-1

LIMITING CONCENTRATIONS OF MINERAL CONSTITUENTS FOR DRINKING WATER

United States Public Health Service Drinking Water Standards, 1946

Constituent	Upper limit of concentration, in parts per million
Fluoride (F)	1.5*
Iron (Fe) and manganese (Mn) together	0.3
Magnesium (Mg)	125
Chloride (Cl)	250
Sulfate (SO_4)	250
Lead (Pb)	0.1*
Selenium (Se)	0.05*
Hexavalent chromium	0.05*
Copper (Cu)	3.0
Arsenic (As)	0.05*
Zinc (Zn)	15
Phenol	0.001
Total solids	500 (1,000 permitted)

* Mandatory upper limits; others are recommended.

"3.21 Of all the standard ten milliliter (10 ml.) portions examined per month in accordance with the specified procedure, not more than ten (10) percent shall show the presence of organisms of the coliform group.

"3.22 Occasionally three (3) or more of the five (5) equal ten milliliter (10 ml.) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than:

(a) Five (5) percent of the standard samples when twenty (20) or more samples have been examined per month.

(b) One (1) standard sample when less than twenty (20) samples have been examined per month.

"Provided further that when three or more of the five ten milliliter (10 ml.) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the sampling point shall be collected promptly and examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality."

Water as supplied to the consumer for domestic or municipal uses should conform to the above standards for drinking water. Where these supplies are used for other purposes, such as incidental irrigation or industrial use, it may be necessary to consider mineral quality requirements for such uses in addition to the requirements for drinking purposes.

An additional factor with which operators of public water supply systems are concerned is the so-called "hardness" of the supplies. Hardness in water is principally due to carbonates and sulfates of calcium and magnesium, and is generally evidenced to the consumer by inability to develop suds when using soap. Hardness is an important consideration to industrial organizations, due to its effect on plant maintenance and manufacturing processes. However, in general domestic use, hardness can result in increased soap consumption, excessive repairs to plumbing, and the necessity or desirability of maintaining individual water softener appliances. Waters which have a hardness below 55 parts per million seldom cause complaint, but above 100 parts per million they may well be termed "hard" and above 200 parts per million can be called "very hard." Treatment to remove hardness is often combined with other treatment processes prior to distribution of the water supply to the consumer.

Irrigation Water. In establishing the *relative* suitabilities of surface and ground waters for irrigation use it is necessary to consider the effects of mineral constituents of the water on both the plant and the soil. The deleterious effects of salts on plant growth can result from: (a) direct physical effects of salts in preventing uptake of water by plants (osmotic effects); (b) direct chemical effects on metabolic reactions of plants; and/or (c) indirect effects through changes in soil structure, permeability, and aeration. The most significant water quality factors in these three types of injury are total dissolved salts, deleterious substances found in low or trace concentrations, and certain percentage combinations of the predominant cations calcium, magnesium, sodium, and potassium, and anions carbonate, bicarbonate, chloride, and sulfate.

The total salt content, the main effect of which is osmotic, is generally stated in terms of specific electrical conductance, a measure of concentration of ions per unit of water, and/or in terms of total dissolved solids in parts per million parts of water. Osmotic effects are caused primarily by the cations calcium, magnesium, sodium, and potassium, and the anions carbonate, bicarbonate, sulfate, chloride, and nitrate, and in part by the constituents present in the water in low or trace concentrations. The individual constituents which may affect metabolic reactions of plants include nearly all of the elements already cited if they are present in abnormally large quantities. Chlorides and sulfates are specifically mentioned in this regard.

Constituents present in water in very low or trace concentrations which seriously affect the metabolic reactions of plants include boron, lithium, iron, and other heavy metals, the exact symptomatic effects of which are presently unknown. Boron is now considered to be the most important minor constituent in water, and is the only so-called "minor" or "trace" element that is routinely considered in evaluating suitability of water for irrigation. Although used by plants in metabolic reactions in small amounts, boron is extremely toxic if present in irrigation water in amounts exceeding from about 0.5 to 2 parts per million.

The percentage combinations of a mineral constituent in water are generally expressed as percentage reacting values to the totals of the cations or anions as the case may be. Per cent sodium is particularly important because, at certain percentage values, sodium reacts with the soil in such a way as to render it relatively impermeable to water and in some instances to plant roots. Such sodium-affected soils are commonly termed alkali soils if carbonates are the predominant anions in the soil solution, or saline soils if chlorides or sulfates are the predominant anions. Sodium-saturated soils, either alkali or saline, characteristically support little or no plant growth.

The limits of permissible mineral concentration in irrigation waters have been resolved into classifications or divisions of the waters into broad categories of quality designated as: "excellent to good," or "suitable under most conditions"; "good to injurious," or "harmful to some plants under certain conditions"; and "injurious to unsatisfactory," or "harmful to most plants under most conditions." Occasionally, these classes have been further subdivided into groupings labeled "excellent," "good," "permissible," "injurious," and "unsatisfactory."

TABLE I-2

CRITERIA FOR CLASSIFICATION OF IRRIGATION WATERS

Reference*	Percent sodium, Na×100 / K+Na+Mg+Ca as milli-equivalents per liter	Conductance, EC×10⁶ at 25°C.	Total salts, in parts per million	Boron, in parts per million: Sensitive plants	Boron, in parts per million: Semitolerant plants	Boron, in parts per million: Tolerant plants	Chlorides, in milli-equivalents per liter	Sulfates, in milli-equivalents per liter
Class I, excellent to good, or suitable for most plants under most conditions								
A	0–60	0–1,000	0–700		0–0.5		0–5	0–10
B	0–30	0–500	0–350	0–0.5	0–1.0	0–1.5	0–5.5	0–5.5
C	0–60	0–750		0–0.5	0–1.0	0–2.0		
Class II, good to injurious, harmful to some under certain conditions of soil, climate, practices								
A	60–75	1,000–3,000	700–2,100		0.5–2.0		5–10	10–20
B	30–70	500–2,500	350–1,750	0.5–1.12	1–2.25	1.5–3.35	5.5–16.0	5.5–16.0
C	60–70	750–3,000		0.5–1.0	1.0–2.0	2.0–3.0		
Class III, injurious to unsatisfactory, unsuitable under most conditions								
A	75–	3,000–	2,100–		2.0–		10–	20–
B	70–	2,500–	1,750–	1.12–	2.25–	3.35–	16–	16–
C	70–	3,000–		1.0–	2.0–	3.0–		

*A California State Water Resources Board, "Water Resources of California." Bulletin No. 1. 1951.
B Scofield, Carl S. "The Salinity of Irrigation Water." Smithsonian Report. 1951.
C Chapman, H. D., Wilcox, L. V., and Hayward, H. E. "Water Quality from an Agricultural Point of View." Report of Interim Fact-Finding Committee on Water Pollution. California State Assembly. 1949.

Five parameters are primarily used in such classifications. These are: (1) per cent sodium; (2) total dissolved mineral solids; (3) boron concentration; (4) chloride concentration; and (5) sulfate concentration. Criteria proposed by various agencies for the classification of irrigation waters are presented in Table I-2. The latest published proposals for irrigation waters are found in "Diagnosis and Improvement of Saline and Alkali Soils," Agricultural Handbook No. 60, Regional Salinity Laboratory, United States Department of Agriculture. The State of California does not have any officially adopted standards for quality of irrigation waters.

It is here noted that the criteria for the classification under Reference A in Table I-2 were taken from information supplied to the Division of Water Resources by Dr. L. D. Doneen, Professor in the Department of Irrigation of the University of California at Davis, and have been used for some time by the Division for classifying irrigation waters.

Recent research performed by Dr. Doneen has pointed out certain inadequacies of the total salt concept, and he has suggested a revision of standards based on a new method for calculating salinity of irrigation water. A statement submitted by Dr. Doneen in regard to the suggested change follows:

"This proposed standard for total salts of an irrigation water is based on the premise that the salts will accumulate in the soil due to evaporation from the soil surface and water used by the plants in transpiration. Plants usually remove only a small percentage of the total salts occurring in the irrigation water. As the soil solution becomes concentrated certain salts will precipitate. Because of the low solubility, the first to precipitate will be calcium carbonate, followed by magnesium carbonate and finally by calcium sulfate. Those salts will not produce a saline soil. Other salts normally occurring in irrigation water in any significant concentration are extremely soluble and accumulate in the soil solution as salines. These salines are listed as 'effective salinity.' Therefore, calcium and magnesium carbonates and calcium sulfate should not be considered in establishing standards for total salts as is now the practice in the use of electrical conductance, total parts per million or milliequivalents per liter concentration.

"The following table suggests standards for effective salinity of the irrigation water with and without restricted drainage. The crucial concentrations are those listed in Class I for the three soil conditions. Class II and III indicate increasing concentration, and the build-up of soil salinity should be checked periodically and irrigation practices adjusted to remove salinity with the minimum loss of water.

"TENTATIVE CLASSIFICATION FOR EFFECTIVE SALINITY OF IRRIGATION WATER

Soil conditions	Terms used	Class I	Class II	Class III
Little or no leaching of the soil can be expected	ion milliequivalents	3	3– 5	5
	parts per million	165	165– 275	275
	lbs/acre-foot	450	450– 750	750
Some leaching but restricted; deep percolation or drainage slow	ion milliequivalents	5	5– 10	10
	parts per million	275	275– 550	550
	lbs/acre-foot	750	750–1500	1500
Open soils; deep percolation of water easily accomplished	ion milliequivalents	7	7– 15	15
	parts per million	385	385– 825	825
	lbs/acre-foot	1050	1050–2250	2250

end of quotation

The relative tolerance of crop plants to salt constituents in the soil solution has been arranged in the order of increasing tolerance in Table I-3. Data presented in this tabulation are based upon research at the University of California and the United States Regional Salinity Laboratories at Riverside.

The tolerance of various crops to boron in irrigation water is presented in Table I-4. Those plants which can withstand only relatively low concentrations are designated as sensitive, an intermediate group as semi-tolerant, and a final group as tolerant. Within a given group the more sensitive plants are listed first. The grouping is based upon research at the University of California and the United States Regional Salinity Laboratory at Riverside.

With regard to bacteriological requirements for irrigation water, the State Department of Public Health has established regulations governing use of sewage for crop irrigation purposes. Pertinent extracts of these regulations state:

"Raw, i.e., untreated, sewage containing human excrement shall not be used for irrigating growing crops. Use of bar screens, grit, or detritus tanks is not to be considered as sewage treatment under these regulations."

* * * * *

"Effluents of septic tanks, Imhoff tanks or of other settling tanks, or partially disinfected effluents of sprinkling filters or activated sludge plants or similar sewages, shall not be used to water any growing vegetables, garden truck, berries, or low-growing fruits such that the fruit is in contact with the ground, or to water vineyards or orchard crops during seasons in which the windfalls or fruit lie on the ground. . . .

"Nursery stock, cotton, and such field crops as hay, grain, rice, alfalfa, sugar beets, fodder corn, cowbeets, and fodder carrots may be watered with such settled or undisinfected or partially disinfected sewage effluents provided that no milch cows are pastured on the land while it is moist with

TABLE I-3

RELATIVE TOLERANCE OF CROP PLANTS TO SALT CONSTITUENTS IN THE SOIL SOLUTION

(In order of increasing tolerance)

Crops which may be grown on soils of weak salinity		Crops which may be grown on soils of medium salinity		Crops which may be grown on soils of strong salinity
Fruit Crops				
Lemon	Almond	Olive		Date palm
Orange	Pear	Grape		
Apple	Grapefruit	Fig		
Plum	Peach	Pomegranate		
Apricot				
Field and Truck Crops				
Green beans		Wheat	Oats	Cotton
Potato		Pepper	Rye	Kale
Sweet potato		Onion	Barley	Rape
Eggplant		Squash	Sorghum	Milo
Artichoke		Spinach	Foxtail millet	Garden beets
Cabbage		Carrot	Asparagus	Sugar beets
Celery		Lettuce	Tomato	
Peas		Cantaloupe	Flax	
Vetch		Sunflower	Alfalfa	
		Rice		
Forage Crops				
Burnet		Sickle milk vetch	Orchard grass	Western wheat grass
Ladino clover		Sour clover	Tall fescue	Beardless wild rye
Red clover		Cicer milk vetch	Alfalfa	Canada wild rye
Alsike clover		Tall meadow oat grass	Herban clover	Rhodes grass
Meadow foxtail		Smooth brome	Sudan grass	Rescue grass
White dutch clover		Big trefoil	Dallis grass	Bermuda grass
		Reed canary	Strawberry clover	Salt grass
		Meadow fescue	Birdsfoot trefoil	Nuttall alkali grass
		Blue grass	Sweet clover	Alkali sacaton

sewage, or have access to ditches carrying such sewage.

"The foregoing restrictions do not apply against the use of well oxidized nonputrescible, and reliably disinfected or filtered effluents which always meet the following bacterial standard: in any 20 consecutive samples, from which five 10 c.c. portions each are examined, not over ten portions shall be positive for members of the Coli-aerogenes group, and in no single sample shall over half the .1 c.c. portions of the sample of the effluent be positive for the above organisms. Samples shall be analyzed according to the latest Standard Methods of Examination of Water and Sewage of American Public Health Association."

It is important that the local conditions be considered carefully before passing judgment on the suitability of a particular water for irrigation. In this connection, a water may be suitable in respect to one characteristic and doubtful or unsuitable in another. Because of great differences in salt tolerance of plants on the one hand, and the influence of natural modifying conditions such as soil permeability, temperature, humidity, and rainfall on the other, it is impossible, for general application, to establish fixed limits. The variables introduced by the soil permeability factor are particularly noteworthy. For example, the rapid percolation of rainfall and irrigation water through permeable sandy soil tends to leach the salts downward, and thus to prevent accumulation of salts in the effective root zone. In heavy clay soils the leaching effects are not as well pronounced, and the salt content builds up at a relatively rapid rate with successive irrigations. In especially heavy soils of restricted permeability it is possible that a twofold or more increase in salt content may develop from use of a given water during a single irrigation season.

In determining the suitability of water for irrigation use, it is necessary to consider the characteristics of the water not only with respect to the conditions of its use, but also with respect to artificial modifications that could be imposed on the conditions of use for the purpose of increasing its usefulness. A modification that may be imposed with respect to water of high sodium content, for example, is the application of gypsum to the irrigation water or to the soil being irrigated. A modification that may be imposed with respect to water of high salt content is the application of excess water to effect leaching. Fertilizers may also be used to enhance suitability of waters for irrigation purposes.

TABLE I-4

TOLERANCE OF VARIOUS CULTIVATED PLANTS TO BORON

(In order of increasing tolerance)

Sensitive	Semi-tolerant	Tolerant
Lemon	Lima bean	Tobacco
Grapefruit	Sweet potato	Carrot
Avocado	Bell pepper	Lettuce
Orange	Tomato	Cabbage
Thornless blackberry	Pumpkin	Turnip
Apricot	Zinnia	Onion
Plum	Oat	Broad bean
Prune	Milo	Muskmelon
Peach	Corn	Gladiolus
Cherry	Wheat	Alfalfa
Kadota fig	Olive	Garden beets
Grape	Rose	Mangel
Apple	Radish	Sugar beets
Pear	Sweet pea	Artichoke
American elm	Cotton	Palms
Navy bean	Sunflower	Asparagus
English walnut	Field pea	Sweet clover
Black walnut	Potato	
Pecan	Celery	
Cow pea	Vetch	
Persimmon	Barley	

Fish and Other Aquatic Life, Including Shellfish. Water of suitable quality is a fundamental requirement for the existence of an abundant supply of food and game fish in California's streams and lakes. Quality of the water must be such as to maintain an abundant supply of food required by fish and other desirable forms of aquatic life. The various substances or impurities carried in solution and suspension by a stream or body of water determine whether the waters present environmental conditions favorable or unfavorable for fish and other aquatic organisms.

The quantity of impurities in water that adversely affects fish life, or a particular form of sustaining aquatic life, is rather difficult to ascertain because of the inter-dependence of most forms of aquatic life. However, waters utilized for the propagation of fish and aquatic life should be free of toxic or harmful concentrations of mineral and organic substances and excessive turbidity. Extensive field and laboratory studies conducted by the United States Fish and Wildlife Service result in the conclusion that the water in streams supporting a mixed population of fish should have the following properties:

(a) Dissolved oxygen not less than 5 parts per million, or at least 85 per cent of saturation.

(b) pH range between 7.0 and 8.5.

(c) Ionizable salts as indicated by a conductivity between 150 and 500 micromhos at 25° Centigrade and in general not exceeding 1,000 micromhos.

(d) Ammonia not exceeding 1.5 parts per million.

(e) Suspensoids of a hardness of 1 or greater, so finely divided that they will pass through a 1,000-mesh (to the inch) screen; and so diluted that the resultant turbidity would not reduce the millionth intensity depth for light penetration to less than 5 meters.

It is indicated that the metallic cations least harmful to fish are sodium, calcium, strontium, and magnesium. Cations of relatively low toxicity are potassium, lithium, barium, manganese, and cobalt. High toxicity to fish is produced by silver, mercury, copper, lead, zinc, cadmium, aluminum, nickel, trivalent chromium, tin, iron, gold, cerium, platinum, thorium, and palladium. Extremely toxic solutions are cupric, mercuric, and silver salts.

If favorable conditions are to be maintained in waters supporting fish and aquatic life, all pollutants not readily oxidizable or removable by the flow of a stream should be excluded. It is particularly important that formation of sludge banks be avoided. The excluded products include particularly all cellulose pulp and wastes carrying heavy metallic ions. In this respect, the California Fish and Game Code is quoted as follows:

> "481. It is unlawful to deposit in, permit to pass into, or place where it can pass into the waters of this State, any petroleum, acid, coal or oil tar, lamp black, aniline, asphalt, bitumen, or residuary product of petroleum, or carbonaceous material, or substance, or any refuse, liquid or solid, from any refinery, gas house, tannery, distillery, chemical works, mill or factory of any kind, or any sawdust, shavings, slabs, edgings, or any factory refuse, or any lime, any cocculus indicus, or any slag, or any substance or material deleterious to fish, plant life, or bird life.
>
> "481.5. Whenever it is determined by the commission that a continuing and chronic condition of pollution exists, the commission shall report such condition to the appropriate regional water pollution control board, and shall cooperate with and act through such board in obtaining correction in accordance with any laws administered by such board for control of practice for sewage and industrial waste disposal."

Increasing use of detergents for household and industrial purposes and the use of poisons and insecticides in agriculture pose a serious hazard to fish life. Modern detergents contain a high percentage of phosphates, which may radically change the entire aquatic biota of the receiving water. Detergents, particularly the nonionic types, are extremely toxic to fish life. Studies by the California Department of Fish and Game indicate that the toxic level for common household detergents may be as low as 10 to 20 parts per million.

Shellfish are readily and adversely affected by contaminated water, and have often been a factor in the transmission of water-borne diseases. Oysters are particularly important in this respect because they are frequently eaten raw. A history of epidemics ascribed to infected shellfish led to the development by the United States Public Health Service, about thirty years ago, of sanitary standards in waters used for growing shellfish which enter interstate commerce. Growing areas are classified, according to density of coliform bacteria of their waters, and according to their freedom from contamination as revealed by a sanitary survey. Three classifications of waters are recognized: "approved," having a median coliform density under 70 per 100 milliliters (ml.), and free from discharges of human sewage; "closed," having a coliform density over 700 per 100 ml., and contaminated by known sources of sewage; and "restricted," an intermediate class of growing areas from which shellfish may be taken only under severe precautions. The California Department of Public Health has adopted regulations to control shellfish production which are based on those of the United States Public Health Service, and uses the bacterial standards cited above as a guide in appraising suitability of shellfish growing areas.

Development and use of water resources, including the construction of dams for storage of water, frequently affect water temperatures which in turn affect fish and other aquatic life. Optimum temperatures for cold-water fish, such as trout and salmon, are not well known, but probably lie between 50° and 60° Fahrenheit. The cold-water species are generally intolerant of temperatures above 61° Fahrenheit, and will seek the lower temperature where possible. Warm-water fish, such as minnows, carp, catfish, perch, sunfish, and bass, normally live in water having temperatures ranging from near 32° to 86° Fahrenheit. Acclimation enables the warm-water species to live in water having temperatures as high as 91° Fahrenheit, although they migrate to waters below 86° Fahrenheit where possible.

Waterfowl are seriously affected by conditions which destroy an abundant supply of aquatic life. Botulism, which has occurred at a number of places in California, accounts for the death of thousands of ducks. The cause of the disease is a toxin produced by bacterial organisms under certain conditions of septicity and temperature. The incidence of the disease has been halted by supplying fresh water to the affected area.

Recreation. No minimum sanitary requirements have been established for natural fresh-water bathing places, but the State Board of Public Health uses the following criteria in establishing quarantine of public salt-water bathing areas:

(1) The area shall be free of visible solids of sewage origin.
(2) The waters shall not contain more than 10 per milliliter of coliform organisms in more than 20 per cent of the samples taken for sanitary analysis.

In addition to the above requirements, waters to be used for recreation should be free from odor, color, grease, suspended matter, floating matter, toxic materials, and constituents adversely affecting aquatic life in natural streams and lakes.

In California the minimum regulations governing artificially constructed swiming pools are set forth by the State Department of Public Health as follows:

> "Every swimming pool shall be provided with an adequate water supply including such water purification works as may be necessary so that (a) the water in the pool shall at all times of use be sufficiently bright and clear that the body of the bather or an object simulating it on the bottom of the pool in its deepest part will be plainly visible from the edge of the pool surrounding the deep end; and (b) the bacterial condition of water in the pool and of water as admitted to the pool shall be such that at all times, including times of intense use of the pool, samples of water taken from any part of the pool will not contain more than 1,000 bacteria per cubic centimeter when plated on standard Agar medium for 24 hours at 37° C., nor B. Coli in more than one of two one cubic centimeter portions of water when confirmed on solid medium . . ."

Navigation. Water quality is incidental to the actual movement of vessels through the water unless navigation is physically blocked by sediment and debris, floating or otherwise. Ships and small boats are frequently damaged by caustic or acid wastes which corrode the paint or cause deposits of unsightly residue on the sides of the vessels. The fire hazard of oil is also important when considering quality standards for navigational waters. In harbors and dockage areas the disposal of organic wastes may corrode the hulls of vessels because of the hydrogen sulfide that is generated from decomposition of the materials. Corrosion of bronze propellers and gunmetal sleeves on propeller shafts is caused by presence of sulfide in polluted waters. These decomposing organic wastes also give off offensive odors.

Salinity Control. One of the principal objectives of the Central Valley Project is to protect the Sacramento-San Joaquin Delta from intrusion of salt water from Suisun Bay. It is necessary to maintain a net inflow of about 3,300 second-feet to the Delta over and above consumptive requirements in the Delta, in order to achieve the objective of maintaining chlorides of no more than 1,000 parts per million in the Sacramento River near Antioch. The necessary volume of water for control of seawater intrusion is met wholly or in part from operation of Shasta Reservoir.

Another salinity problem that is of increasing importance is the accretion to streams of waters containing large amounts of dissolved minerals, principally return waters from irrigation. Control of this type of salinity is best achieved by dilution with water of low mineral content. The success of the control measures, in this instance, is dependent not only on the volume of water that can be made available for this purpose, but also upon the mineral content of the diluting water. The quality requirements for this purpose are variable and cannot be readily formulated except as related to a specific stream and plan of development.

Industry. Industrial uses of water are quite variable with regard to suitable water quality. Requirements vary from the extremely exacting criteria for make-up water for high-pressure boilers to the very low requirements of water used for cooling condensers in steam plants. Make-up water for high-pressure boilers must be limited to extremely low concentrations of dissolved mineral solids and organic matter, whereas even sea water may be used for cooling of condensers.

Industrial waters include those utilized for food processing purposes. With the single exception of fish canning operations, such waters must at least conform to the quality standards previously cited for drinking water supplies. Some food processing industries are even more exacting with respect to water quality, particularly from the standpoint of concentration and composition of mineral solubles.

Bacteriological and quality standards of the State Board of Public Health for salt water used in fish canning operations are quoted as follows:

"(a) Waters satisfactory without treatment
- (1) For whole fish handling operations:
  - a) Not subject to contamination with human fecal discharges
  - b) Maximum of 7 E. coli organisms per cc
  - c) Bacterial Standard may be exceeded in not more than 5% of the samples

(b) Waters satisfactory after treatment
- (1) For whole fish handling operations:
  - a) Not subject to gross contamination with human fecal discharges before treatment
  - b) Maximum of 3 E. coli organisms per cc after treatment
  - c) Bacterial Standard may be exceeded in not more than 20% of the samples
- (2) For cut fish handling operations:
  - a) Not subject to gross contamination with human fecal discharges before treatment
  - b) Maximum of 3 E. coli organisms per cc after treatment
  - c) Bacterial Standard may be exceeded in not more than 5% of the samples
  - d) The treatment shall include filtration or the equivalent as one of the steps of the treatment process

TABLE I-5

WATER QUALITY FOR INDUSTRIAL USES[a]

(Allowable limits, in parts per million)

Use	Turbidity	Color	Odor and taste	Iron as Fe	Manganese as Mn	Total solids	Hardness as $CaCO_3$	Alkalinity as $CaCO_3$	Hydrogen sulfide	Miscellaneous requirements: Health	Miscellaneous requirements: Other
Air conditiong			Low	0.5[b]	0.5				1.0		No corrosiveness or slime formation.
Baking	10	10	Low	0.2[b]	0.2				0.2	Potable	
Brewing											
Light beer	10		Low	0.1[b]	0.1	500		75	0.2	Potable	NaCl less than 275 parts per million—pH 6.5-7.0.
Dark beer	10		Low	0.1[b]	0.1	1,000		150	0.2	Potable	NaCl less than 275 parts per million—pH 7.0 or more.
Canning											
Legumes	10		Low	0.2[b]	0.2		25-72		1.0	Potable	
Carbonated beverages	2	10	Low	0.2	0.2	850	250	50–100	0.2	Potable	Organic color plus oxygen consumed less than 10 parts per million.
Confectionery			Low	0.2[b]	0.2	100			0.2	Potable	pH above 7.0 for hard candy.
Cooling	50			0.5[b]	0.5		50		5.0		No corrosiveness or slime formation.
Food, general	10		Low	0.2[b]	0.2					Potable	
Ice	5	5	Low	0.2[b]	0.2		50			Potable	SiO_2 less than 10 parts per million.
Laundering				0.2[b]	0.2		50				
Plastics, clear	2	2		0.2[b]	200.0	200					
Paper and pulp											
Ground wood	50	20		1.0[b]	0.5		180				No grit or corrosiveness.
Kraft pulp	25	15		0.2[b]	0.1	300	100				
Soda and sulfide	15	10		0.1[b]	0.05	200	100				
High-grade, light papers	5	5		0.1[b]	0.05	200	50				
Rayon (viscose)											
Pulp production	5	5		0.05[b]	0.03	100	8	Total 50; hydroxide 8			Al_2O_3 less than 8 parts per million; SiO_2 less than 25 parts per million; Cu less than 5 parts per million.
Manufacture	.3			0.0	0.0		55				pH 7.8 to 8.3.
Textiles, general	5	20		0.25	0.25						
Dyeing	5	5–20		0.25[b]	0.25	200					Constant composition; residual alumina less than 0.5 parts per million.

[a] From "Progress Report of the Committee on Quality Tolerances of Water for Industrial Uses." Journal New England Water Works Association. Volume 54, Page 271. 1940.
[b] Limit given applies to both iron alone and the sum of iron and manganese.

"Samples for bacteriological analysis shall be analyzed by an approved method set forth in the latest edition of the APHA Manual entitled, 'Standard Methods for the Examination of Water and Sewage.' Those methods shall be employed which give the most specific reliable means of measuring organisms having their origin in the intestines of man and other warm-blooded animals."

Because of the large number of industrial uses of water and the extremely varied requirements, it is difficult to establish other than broad requirements of quality. These variable conditions make it desirable to consider water quality in general terms and, where possible, for groups of related industries. The general quality requirements of several individual and major groups of water uses are listed in Table I-5.

Quality requirements for boiler make-up waters are more exacting than those set forth in Table I-5, and the allowable concentrations of physical and mineral characteristics for that use are presented in Table I-6.

Recharge of Ground Water. In general, the mineral quality of water that is to be used for recharge should be at least comparable to the quality of the native ground waters. However, in those instances where the native ground waters are of very high mineral quality, it may be reasonable to use a water of somewhat lower quality for recharge. Conversely, where the ground waters are close to the border line

TABLE I-6

WATER QUALITY LIMITS FOR BOILER FEED WATER[a]

(Allowable limits, in parts per million)

Item	Pressure, in pounds per square inch: 0–150	150–250	250–400	Over 400
Turbidity	20.0	10.0	5.0	1.0
Color	80.0	40.0	5.0	2.0
Oxygen consumed	15.0	10.0	4.0	3.0
Dissolved oxygen[b]	1.4	0.14	0.0	0.0
Hydrogen sulfide (H_2S)	5.0[c]	3.0[c]	0.0	0.0
Total hardness as $CaCO_3$	80.0	40.0	10.0	2.0
Sulfate-carbonate ratio (A.S.M.E. Na_2SO_4:Na_2CO_3)	1:1	2:1	3:1	3:1
Aluminum oxide (Al_2O_3)	5.0	0.5	0.5	0.01
Silica (SiO_2)	40.0	20.0	5.0	1.0
Bicarbonate (HCO_3)[b]	50.0	30.0	5.0	0.0
Carbonate (CO_3)	200.0	100.0	40.0	20.0
Hydroxide (OH)	50.0	40.0	30.0	15.0
Total solids[d]	3,000–500	2,500–500	1,500–100	50.0
pH value (minimum)	8.0	8.4	9.0	9.6

[a] Moore, E. W. "Progress Report of the Committee on Quality Tolerances of Water for Industrial Uses." Journal New England Water Works Association. Volume 54, Page 263. 1940.
[b] Limits applicable only to feed water entering boiler, not to original water supply.
[c] Except when odor in live steam would be objectionable.
[d] Depends on design of boiler.

with respect to quality for the uses thereof, only waters of higher quality should be used for artificial recharge. Recharge waters should not contain substances which are toxic either in character or concentration, and the ground water should not be contaminated with pathogenic organisms.

Mining. The quality of water required for mining uses will vary depending on the type of material mined and the methods used in processing the ore. The water should not contain constituents which would react with chemicals used in the operation and adversely affect production, nor should the water contain constituents which would damage machinery or other equipment with which it may come in contact.

CAUSES OF DETERIORATION OF WATER QUALITY

Before considering the major causes of impairment of water quality it may be helpful to classify them by type. Ample legal precedent exists for such classification. The California Legislature, in 1949, recognized two types of deterioration, namely, contamination and pollution, both of which are defined in Section 13005 of the Water Code.

Contamination is defined as impairment of the quality of the waters of the State by sewage or industrial waste to a degree which creates an actual hazard to the public health through poisoning or through the spread of disease. This comprehends only those wastes resulting from human activity which contain, or may contain, physiologically harmful amounts of toxic or irritant substances, or pathogenic organisms.

Pollution is defined as impairment of the quality of the waters of the State by sewage or industrial waste to a degree which does not create an actual hazard to the public health, but which does adversely and unreasonably affect such waters for domestic, industrial, agricultural, navigational, recreational, or other beneficial use. This recognizes the detrimental economic effects of the uncontrolled discharge of sewage and industrial wastes.

There is another type of impairment of quality of water which concerns neither sewage nor industrial wastes. In some cases, the presence of man may be immaterial, and in others his activity may be only an indirect or contributing factor. The term "degradation" has been adopted for this type of impairment, which comprises all damage to quality of water not due to disposal of sewage or industrial wastes.

Among the more common causes of impairment in quality of waters are the following:

Contamination and Pollution

1. Domestic and municipal sewage
2. Industrial wastes
   - A. Organic wastes
     - (1) Food processing
       - (a) Fruit and vegetable canneries
       - (b) Fish canneries and fish reduction plants
       - (c) Slaughtering plants
       - (d) Wineries
       - (e) Breweries
       - (f) Sugar refineries
     - (2) Lumber processing
       - (a) Mill ponds
       - (b) Sawdust and bark
       - (c) Pulp mills
   - B. Mineral wastes
     - (1) Metal processing industries
       - (a) Plating works
       - (b) Steel mills
     - (2) Mining and ore extraction industries
       - (a) Drainage from mines
       - (b) Water from processing ores
       - (c) Dredging
       - (d) Gravel pits
     - (3) Oil industries
       - (a) Drilling wastes
       - (b) Production wastes, brines, oils
       - (c) Refinery wastes
       - (d) Terminal loading wastes
       - (e) Abandoned oil and gas wells
     - (4) Chemical industries
     - (5) Miscellaneous
   - C. Cooling water
3. Solid and semi-solid refuse

Degradation

1. Effects of development, use, and re-use of water
   - A. Irrigation return water
     - (1) Surface drainage
     - (2) Percolation
   - B. Interchange between aquifers due to improperly constructed, defective, or abandoned wells
   - C. Interchange between aquifers due to differentials in pressure levels resulting from excessive withdrawal
   - D. Overdraft conditions
     - (1) Sea-water intrusion
     - (2) Salt balance
     - (3) Upward or lateral diffusion of connate brines and/or juvenile water due to overpumping
   - E. Contamination from the surface due to improperly constructed wells

2. Natural causes
   A. Inflow and/or percolation of juvenile water from highly mineralized springs and streams
3. Other causes
   A. Accelerated erosion
   B. Mineralization resulting from plant transpiration and/or evaporation

The effects of improperly constructed and abandoned wells, although locally serious, are not involved in the development of The California Water Plan, and hence are not discussed further here.

Domestic Sewage

The most widely known cause of impairment of water quality is domestic or municipal sewage. Three general types of sewage have been distinguished, which are:

a. *Sanitary sewage*, a watery mixture or suspension of solid and liquid wastes resulting from man's metabolism and domestic habits.

b. *Storm sewage*, the runoff from the surface of the land, originating in natural precipitation, that may be admitted or infiltrate into a drain not used for conveyance of sanitary sewage.

c. *Combined sewage*, a mixture, in varying proportions, of the two preceding types.

Sanitary sewage has the greatest effect as a cause of contamination and pollution and usually contains from 0.02 to 0.05 per cent (200 to 500 parts per million) of solid wastes, of which two-thirds or more may be putrescible organic matter. It is readily amenable to treatment to reduce its harmful properties, and an elaborate technology has been developed for treatment by chemical, mechanical, and biological processes. The quantity of sanitary sewage produced is related to water consumption, and generally varies between 50 and 100 gallons daily per capita in urban areas. A city of 10,000 population, therefore, may be expected to discharge up to 1,000,000 gallons per day of sanitary sewage, containing, in its untreated state, one to two tons of putrescible sewage solids.

Storm sewage is normally lower in organic matter than sanitary sewage and may be discharged harmlessly into many surface waters. It usually contains a small amount of polluting organic matter picked up in its flow over the surface. In addition, it is likely to carry a considerable amount of suspended mineral matter flushed off the ground. This suspended matter, commonly called grit, may need to be removed if the sewage is to be pumped or treated.

Combined sewage is of declining importance, since modern engineering practice provides separate systems for sanitary and storm sewage. Combined systems are still found in some older communities in California, notably in the San Francisco Bay Area. An extensive program for their elimination has been followed in recent years.

Sewage solids may be present in receiving waters in a dissolved, colloidal, or suspended state. Those solids which settle out of the water form concentrated mixtures of unstable organic compounds commonly termed sludge. Under the action of biological organisms, the solids slowly decompose into mineral and relatively stable organic materials. Decomposition of sewage solids take place under stream conditions where oxygen dissolved in the water is available (aerobic) or where dissolved oxygen has been exhausted (anaerobic). Aerobic decomposition is orderly and inoffensive. In absence of sufficient oxygen (anaerobic) these solids slowly decompose or putrefy, producing various odorous and unsightly substances, solid, liquid, or gaseous. During the process of aerobic decomposition dissolved oxygen is removed from the water. The quantity of oxygen required is definitely measurable and is known as biochemical oxygen demand or the "BOD" of the sewage. This demand may be so large as to exhaust completely the oxygen content of the receiving waters.

The crux of this situation is that certain irreducible minimums of dissolved oxygen are needed to maintain a semblance of clean waters without nuisance. These minimums have been variously estimated at 25 to 50 per cent of the saturation value, or theoretical maximum. Lacking sufficient oxygen, stream degradation sets in quickly. The sewage solids decompose with production of foul odors and gases; noxious bacteria multiply; the stream becomes black, greasy and unsightly; and fish and other denizens of normal waters die.

In recent years the phosphorus content of sewage has been greatly increased due to use of cleansing detergents which contain phosphates. Such detergents magnify the problems of sewage and water treatment plants. The phosphates added to receiving streams and lakes through sewage and industrial cleansing waste disposal, under certain conditions, are capable of causing excessive growth of undesirable algae to an extent that fish life is destroyed and offensive odor and water taste is created.

The undesirable effects of sewage pollution of water may be summed up as follows:

a. Sewage bacteria, except in minute concentrations, render water unfit for drinking and other personal and domestic uses.
b. Such bacteria also impair water quality for swimming and similar recreational purposes.
c. Gross pollution by sewage destroys all normal aquatic life of receiving waters.
d. Certain sewage gases, notably hydrogen sulfide, are corrosive to metals and harmful to paints. Much damage has been done to ships' hulls and other submerged and floating structures by contact with waters heavily polluted with sewage.

e. Waters made unsightly or odorous by sewage depreciate the value of shore property.
f. Sewage pervading waters utilized for culture of shellfish may cause them to become unsafe for consumption. Such shellfish beds must be condemned by health authorities, and a valuable food resource is thereby destroyed.
g. Sewage pollution may make water unsafe for certain agricultural uses, for example, stockwatering, especially of dairy cattle, and the irrigation of truck garden crops.
h. Phosphates in sewage create undesirable conditions in receiving water as regards its biota. Excessive growth of algae may deoxygenate the stream, destroy fish life, and give rise to offensive odors and water taste.

Solid and Semisolid Refuse

The rapid growth of population and industry in California has created acute problems in the disposal of solid and semisolid wastes in many areas, particularly in southern California. This class of materials comprises all wastes not discharged into public sewers. Three general classes may be distinguished, in decreasing order of chemical activity and their potential for polluting public waters: (1) general industrial wastes, including acids, alkalies, sludges, slurries, organic chemicals, solvents, tars, spent lubricating oils, etc.; (2) general domestic and municipal refuse, including such substances as tin cans, junk metals, paper and paper products, cloth, lawn and shrubbery clippings, garbage, and dead animals; and (3) solid and relatively inert waste products, such as earth, concrete fragments, glass, plasterboards, steel mill slag, and manufactured rubber products. Population pressure and rises in value of land have made it no longer cheap or easy, in many cases, to obtain refuse disposal sites which are sufficiently isolated, and at the same time close enough to be within economical hauling distance. In southern California especially, such sites are at a permium, current sales of dump sites having reached a price as high as 50 cents per cubic yard of capacity.

During the past few years the Division of Water Resources, the State and Regional Water Pollution Control Boards, and other agencies have been actively concerned in investigation of this problem. Studies by the Division of Water Resources for the Los Angeles, Santa Ana, and San Diego Regional Water Pollution Control Boards have resulted in the development of a system of classification for dump sites, according to the degree of protection which they afford the vicinal ground water. Class I dump sites are defined as "sites located on nonwater-bearing rocks or underlain by isolated bodies of unusable ground water, which are protected from surface runoff and where surface drainage can be restricted to the site or discharged to a suitable waste way." Class II sites are those "underlain by usable, confined or free ground water when the minimum elevation of the dump can be maintained above anticipated high ground water elevation, and which are protected from surface runoff and where surface drainage can be restricted to the site or discharged to a suitable waste way." The poorest dump sites are those in Class III, which are defined as "dump sites so located as to afford little or no protection to usable waters of the State."

Refuse disposal sites in the first or safest class are considered satisfactory to receive any type of refuse without hazard to ground or surface waters. Dump sites in the second class are considered satisfactory to receive solid inert wastes, as well as the types of domestic and municipal refuse mentioned in the opening paragraph of this section, provided that dumping is confined to zones not less than two to five feet above anticipated high ground water elevations in the vicinity. Solid, inert materials as previously described may be deposited safely in a dump of any class.

Formal recommendations have been made by the Division of Water Resources for the protection of ground waters from the effects of unregulated dumping of wastes in the Santa Ana and San Diego regions and in Los Angeles County.

The investigations of the Division of Water Resources have been most usefully complemented by research carried on by the University of Southern California under the sponsorship of the State Water Pollution Control Board. Reports published in 1952 and 1954 describe the hazards to be anticipated from improper disposal of incinerator ash and of sanitary land fill, and the precautions which should be observed to minimize risk of pollution of ground waters.

Industrial Wastes

The variety of industrial wastes is almost infinite and the quantities, strength, and toxicity may be such as to greatly exceed the effects of ordinary sewage. Certain wastes produced by typical industries important to the California economy, such as the food canning, sugar refining, and meat packing trades, may require from ten to a hundred times more oxygen than domestic sewage in order to be rendered harmless. Metal-working and plating industries produce poisonous wastes, such as chromates and cyanides, which can render water unfit for fish life and unsafe for domestic or municipal use in concentrations as low as one part in ten million. The beet-sugar industry in California has been estimated to produce liquid wastes equivalent in pollutional effect to the sewage of 5,000,000 people before treatment. Enormous loadings of organic wastes have been discharged into certain of the waters of California by food processing plants.

Fruit and Vegetable Canneries. About one-half of the nation's supply of fruits, and one-fourth of the vegetable specialty crops are produced and processed in California. Despite growing diversification of our economy, agriculture and the associated processing activities continue to be the State's largest industry, and the canning of fruits and vegetable products is an important segment of that activity.

Canning-factory wastes vary in nature according to the products handled, and according to the type of factory, i.e., whether the plant is a full-line establishment processing a variety of products, or a specialty plant packing only one item. In general, the liquid wastes from full-line plants are large in volume and not much stronger than sewage in regard to their oxygen requirements. However, the effluent of specialty canneries is likely to be much more concentrated, displaying an oxygen demand of two to fifty times that of an equal volume of sewage. In addition to liquid wastes canneries produce large volumes of solid wastes such as seeds, skin, pulp, pits, etc.

Direct discharge of untreated cannery wastes into municipal sewerage systems would in many cases create an intolerable burden on the sewage treatment facilities. At some locations, facilities are adequate for treatment of the liquid cannery wastes, after removal of part of the solids by screening or sedimentation at the cannery. At a few locations, special treatment works to handle the flow of industrial wastes have been constructed, in addition to the facilities provided for treatment of sewage. In other cases, provision must be made by the individual industry for treatment of its wastes to a point where they can safely be discharged into the State's waters.

The most prevalent method for cannery waste treatment in California is screening to remove part of the solids, followed by sedimentation and biological oxidation in open ponds or lagoons. Disposal of solids is usually by dumping, spreading, or plowing into privately owned land, and for hog feed. In a few cases, by-products of economic value can be recovered from solid wastes. Other forms of treatment such as chemical precipitation of solids, partial stabilization of liquid wastes in trickling filters, and chlorination, are feasible and are widely practiced throughout the United States. With increasing land values, the food processing industry in California may be impelled to adopt such methods in the interest of economy, as the system of lagooning requires extensive areas of land, as well as isolation, in order to minimize the odor nuisance.

Beet-Sugar Refineries. The beet-sugar industry is historically important in California. The first successful beet-sugar factory in the United States was founded in 1866 at Alvarado. From that beginning the industry has grown to one that annually processes more than 2,500,000 tons of beets. Latest available statistics (1949) indicate a yearly output of beet-sugar and byproducts worth more than $25,000,000.

Geographically the industry is well distributed in California. Major centers of production are in the valleys of the Sacramento, Salinas, and northern San Joaquin Rivers, and the Imperial Valley. Other important producers are located in Alameda, Santa Clara, Santa Barbara, Ventura, Los Angeles, and Orange Counties. The activities of the refineries are seasonal. In northern California the season lasts from August to December, while in the southern part of the State the season is usually somewhat longer, extending from May through December.

The wastes of beet-sugar refineries are characterized by large volume, high BOD, and a large content of suspended and dissolved solids. Introduction of untreated beet-sugar wastes into a stream can cause mass killing of fish, inhibition of diatom growth, stimulation of sewage fungus, and the destruction of normal benthol organisms. The lethal effect is attributed to a combination of the deoxygenating effect of the BOD and the toxicity of the beet saponins.

Waste water flows of several million gallons per day are not unusual. Liquid wastes consist of various wash waters, pulp-press water, and process liquors used in extraction of the sugar. Additionally, it is necessary to dispose of a large amount of spent lime slurry which is used in the refining process. The organic wastes vary widely in strength. Wash waters are often comparable to sewage in respect to BOD, while wastes from the so-called Steffens process may be as much as forty times as great. Suspended solids content is likely to be high in all types of wastes of this industry. Beet pulp, the solid residue of the sugar refining process, has high economic value for cattle feed, and the salvage of the maximum amount of this profitable by-product is of benefit to the industry.

Treatment of the wastes often consists simply of clarification and oxidation in shallow artificial ponds or lagoons. Liquids may be discharged through a series of such ponds, each one successively removing a portion of the suspended matter and contributing some of the oxygen needed for ultimate stabilization of the organic matter present. Efforts are frequently made to provide pond capacity great enough to hold the seasonal discharge so that no waste need be discharged into surface streams. In such cases the liquid is dissipated by evaporation and by percolation into the ground.

Disposal methods as outlined above have the disadvantage of requiring ample land area and are becoming increasingly uneconomic as land values rise. Ponds must be isolated in order to obviate odor complaints by nearby property owners.

Sugar factory wastes respond well to some of the methods employed to treat domestic sewage, including coagulation, settling, and filtration. These methods are often used in other regions, and in Europe, where high land cost is a deterrent to the ponding system. Considerable research has also been made upon processes to eliminate, recirculate, or salvage waste waters from some of the refining processes, with varying degrees of success.

Oil Field Wastes. Petroleum seeping from natural springs was known to the aboriginal inhabitants of California, but it was not until about 1861 that the first well was drilled for oil. Throughout the closing years of the nineteenth century production increased slowly. By 1895 annual output exceeded 1,000,000 barrels. The automobile and two world wars stimulated production to such a degree that during 1951 nearly 357,000,000 barrels were withdrawn from over 29,400 producing wells. For many years the petroleum industry has been outranked only by agriculture in the value of production to the economy of the State. At present California produces about one-sixth of the national supply of crude petroleum.

Water underlies oil in most oil fields. Such water is usually saline to a degree sometimes exceeding that of ocean water. The production of waste water from California oil fields in 1951 amounted to about 562,000,000 barrels (73,000 acre-feet), an average of 1.58 barrels of water to each barrel of oil. Dissolved salts are not the only objectionable ingredients of oil field waste water, or brine. The separation of crude oil and water is seldom complete in the field, and a small percentage of oil is inevitably wasted with the brine. Additional losses associated with oil production occur by accidental spills, leaks, and washing of equipment.

Preservation of quality of both surface and ground waters requires that oily and highly saline wastes be prevented from reaching usable water supplies. Concentrations of chlorides above 300-500 parts per million make water unpalatable, and at about 1,000 parts per million it becomes practically undrinkable. Most crops cannot tolerate more than 350 parts per million of chlorides in irrigation water, nor more than 2,000 parts per million of total dissolved solids. Boron, a frequent ingredient of oil field brines, is injurious to many fruit trees in concentrations as low as one part per million. Fish are killed by concentrated oil field brines, and cattle or hogs drinking such waters may be severely affected. Oil in surface waters is an unsightly and persistent nuisance, and destroys their value for most beneficial uses.

At present there is no economically feasible method of demineralizing oil field brines. Disposal must be made in such a way that fresh water resources will not be affected unreasonably. Operators of coastal oil wells, such as those in portions of Los Angeles and Orange Counties, can usually discharge brines directly into the ocean without harm, except for the residual oil content which may adversely affect fish and aquatic life, and adjacent beaches. Careful separation of the oil is a corollary requirement in such cases.

The disposal problem is more difficult for interior fields, such as those of the western San Joaquin basin, which generally yield highly concentrated, strong brines. Safe disposal there requires either: (1) physical transport of the brines to areas where surface spreading and percolation will do no damage; (2) evaporation in lined, impervious sumps; or (3) return to deep subterranean strata by pumping into abandoned oil wells or specially drilled injection wells. These methods of disposal are costly, and both experience and judgment are needed in their selection.

Irrigation Return Flow

Irrigation waters not consumptively used by the crops but disposed of through surface runoff and deep percolation constitute a major cause of degradation to natural surface and underground water resources of California. The amount of this return flow varies widely with irrigation practices and with different soil conditions and crops, but generally losses amount to about one-half to one-third of the applied irrigation water. Estimates by the Division of Water Resources indicate that about three acre-feet of irrigation water is applied annually to approximately 7,000,000 acres of farm lands in California. Assuming for purposes of illustration an over-all irrigation efficiency of about 66⅔ per cent, the total annual irrigation return flow would amount to about 7,000,000 acre-feet.

Basic research has as yet been accomplished only to a minor extent in evaluating the adverse effects of irrigation losses on quality of receiving waters. However, available data for surface streams indicate that the effects on such supplies are quite serious. This is particularly true of the Sacramento and San Joaquin Rivers in the Central Valley Area and the Santa Ana River in the South Coastal Area. Irrigation losses returning to these streams either as surface or subsurface inflow cause significant changes in both the concentration and composition of mineral solubles therein. For example, in June, 1953, the irrigation drainage that gained access to a 57-mile stretch of the San Joaquin River between Temple Slough and Fremont Ford had increased the dissolved mineral content of water in the stream from its natural content of about 35 parts per million to 420 parts per million. The increased mineralization of water in surface streams is in turn reflected in waters of underground reservoirs recharged thereby. This fact may account in part for the increase in content of dissolved solids that has occurred since 1931 in the underground waters of the Santa Ana River Forebay below Santa Ana River Narrows.

Another important aspect which requires consideration is the effect of irrigation runoff on the biological environment of surface waters. Nitrates and phosphates are especially important in this regard since both are added as fertilizers to the soil or to the irrigation water. Nitrates and phosphates are necessary nutrients to the biota of lakes, reservoirs, and rivers. The greater the percentage of phosphorus and nitrates the more extensive is the growth of both algae and higher plants. Such teeming populations of algae, called "blooms," create at least three water quality problems: first, an overproduction of oxygen during daylight hours, which may cause death of fish by anoxemia (a condition similar to the "bends" suffered by deep-sea divers); second, a complete exhaustion of dissolved oxygen in the water at night, owing to its extraction by algae in their metabolic life-processes after photosynthesis has ceased; and third, the creation of offensive tastes and odors owing to death and decomposition of algae on a scale vastly exceeding normal, or to the very presence of certain species.

Insecticides and herbicides may also be classed as potential pollutants of surface waters. This is especially true after heavy rains in instances where a herbicide is used to control plant growth along stream channels and algal growth in tributary irrigation drains. Recent increases in use of airplane sprays for plant and insect control have aggravated this problem.

Sea-Water Intrusion

Geologic evidence indicates that water-bearing deposits along the seaward and bayward margins of the ground water basins bordering the California coast and inland bays may be in direct contact with the ocean or bay floor, or may extend beneath the floor as confined pressure aquifers and at some distance offshore be in contact with sea water. Long continued draft, a protracted period of dry years, and increasing agricultural, municipal, and industrial demands since 1940, have lowered ground water elevations below sea level along the seaward margins of many of these basins. As a result, the natural seaward hydraulic gradient has been reversed and sea water has encroached upon the coastal margins of many ground water basins.

Encroachment of sea water has already occurred, or an immediate or potential danger of intrusion exists in at least 80 major and minor ground water basins bordering the California coast and inland bays. Of this total, there is definite evidence of intrusion into 13 basins, immediate danger exists in 7 basins, and potential danger exists in 15 basins and probably in an additional 45 basins about which little is known.

Extensive damage due to sea-water intrusion has already occurred in numerous basins, with resultant large economic losses. Unless measures for prevention and control of this source of degradation are undertaken in the near future, further widespread deterioration of ground water supplies will follow.

Connate Waters

Connate waters are those waters entrapped in the interstices of a sedimentary rock at the time it was deposited. These waters may be fresh, brackish, or saline. They are, however, predominantly sodium chloride in type and are of a quality unsuitable for domestic and irrigation purposes.

Connate waters are generally found in water-bearing lenses of Tertiary rocks which underlie or flank the unconsolidated fresh-water-bearing Recent and Plio-Pleistocene deposits. In some instances, flushing of connate saline waters in the unconsolidated Quaternary deposits has been incomplete, resulting in isolated bodies of diluted connate saline waters within the main body of fresh water.

Degradation of fresh-water-bearing deposits by connate saline waters of poor quality is apparently directly related to ground water extractions. As ground water levels in a basin are drawn down, hydraulic gradients may be established which would allow connate saline waters in sediments adjacent to a ground water basin to enter and degrade fresh water aquifers, or connate saline waters underlying the main body of fresh water to migrate upward in areas of heavy ground water extractions. Deep wells may penetrate connate saline waters underlying fresh waters and pump from the saline bottom waters or allow interchange between saline and fresh-water bodies.

Very little information is available to indicate the extent of degradation of fresh-water-bearing deposits by connate saline waters. Evidence accumulated to date indicates that some degree of degradation due to invasion by these waters has taken place in at least 10 ground water basins in California.

Inflow From Highly Mineralized Natural Waters

A common cause of degradation of water occurs through the mingling of natural surface waters of widely different mineral quality. Numerous instances have been found among streams of the State where a soft water of low mineral content in one stream is degraded by inflow of inferior quality from a branch or tributary. The offending water may originate in a mineral spring, inflow from a saline lake, in mine drainage, or in artesian discharge from an abandoned well. However, in most instances, the differences in quality may be attributed to the mineralogical characteristics of the respective drainage basins.

Land Erosion

Land erosion is the process of wearing away of the land surface by the action of running water, wind, or other agents. Erosion is divided into the general classifications of geologic, or normal erosion, and soil, or accelerated erosion. Soil erosion follows as the result of unbalancing the normal equilibrium of natural processes of soil building and soil transportation by activity of man in agricultural and industrial endeavors, as well as by other causes, such as rodent infestation, etc.

When man disturbs the soil cover he causes accelerated erosion to occur. Agricultural development has made waste areas out of many once rich agricultural lands. There are no geographical limits to this destruction. Archeologists have uncovered many buried cities in the deserts of the world. These indicate that many civilizations have ceased to exist because of the effects of erosion. Wasteful erosion is due largely to man's unbalancing of nature's soil equilibrium, and also to his lack of conservation and control methods and practices. Removing the soil cover destroys nature's means of preventing erosion. Vegetative cover decreases the destructive velocity of runoff and cushions the effect of wind and impact of raindrops. Vegetation also functions as minute debris dams, for as particles of soil are transported either by water or wind the vegetation tends to intercept and stop their movement. Vegetation also acts as a soil binder through action of the root systems in keeping the soil particles clustered together. The vegetative soil cover is removed by tillage and only partially replaced by the planting of crops. In some cases, the total area is planted to crops but the land is laid bare for the destructive effect of erosion between plantings. Irrigation also adds its effect to the erosion resulting from natural causes. Soil thus lost becomes part of the stream into which the return water enters. A phase of agriculture which tends to aggravate erosion is the pasturing of cattle, sheep, goats, horses, and other domestic animals. The stock consumes the covering grasses and reduces the protection of the underlying soil.

Industrially, man causes accelerated erosion by mining, by the release of large quantities of water from storage as a result of developing the power resources of water, by quarrying for gravel in the stream bed, and in the harvesting of lumber. Mining, through disturbance to the surface soil and the addition of waste material obtained from within the earth, is an accelerated soil erosion agent. Surface mining, whether open pit, placer, hydraulic, or dredging, accelerates natural soil erosion. In timbering operations the vegetative cover crop is removed, and temporary roads are built which lay open the soil to the erosional forces of wind and rain. Utilization of streams as a means of transportation for logs creates disturbance to the stream bed and increases soil and bed load movement.

The detrimental effects of accelerated soil erosion are numerous. Silt, the product of accelerated soil erosion, is both a pollutant and a degradant. The silt resulting from agricultural and stream bank erosion constitutes a degradant to natural waters. Erosional characteristics which result from mining and quarrying operations constitute pollutants. However, the harmful effects produced by each of the above are similar, and the only practical difference in the two types of erosion is that it is possible to compel the abatement of pollution due to erosion. Silt and other debris created by mining, with emphasis on hydraulic and placer mining, is a deterrent to fish and wildlife propagation and to navigation. Other beneficial uses of the water adversely affected by silt or other debris are recreational uses, irrigation by diversion or pumping of natural or artificial streams, power development, and municipal and industrial uses.

WASTE-LOADING CAPACITY OF NATURAL AND ARTIFICIAL STREAM CHANNELS

Prior concepts of maintaining an arbitrary standard of quality in water resources are yielding to the newer ideas of economic utilization. This doctrine postulates reasonable use of water resources for all beneficial purposes, including use for waste disposal. It recognizes the fact that purity and safety of a water are relative and must always be appraised with reference to its intended use. Pollution must be evaluated in relation to the local situation. Thus, a waste discharge that would be intolerable in Lake Tahoe might be quite permissible in San Francisco Bay.

In California, domestic water supply and irrigation, in that order, are legally recognized as the paramount uses of water. Many other beneficial uses are universally acknowledged, including maintenance and propagation of fish and wildlife, sport and commercial fishing, shellfish culture, stock watering, food processing, industrial process water, power development, navigation, and recreational uses. Waste disposal is a legitimate use but must be controlled to the extent necessary to prevent adverse unreasonable deterioration of the water for some higher purpose. It is further recognized that treatment of wastes is required only to the extent necessary to preserve actual or definitely planned stream uses.

From the ideas expressed above, it follows that the allowable waste-loading capacity of a specific water resource, like water quality, must be evaluated in relation to water uses. The principal patterns of use usually recognized for perennial streams in California are hereinafter set forth. Rivers originating in mountainous, snow-fed areas, characterized by waters of high purity, are generally devoted to those uses of water requiring highest quality, and thus require maximum protection from contamination and pollution. Their waste-loading capacity therefore is practically nil. As the streams enter the valley floor, use for irrigation and industrial purposes is intensified. Use of the streams for waste disposal is often unavoidable, and some deterioration in quality must be accepted as the price of development of agriculture and industry. Finally, in the lower reaches extending to tidewater, discharges resulting from urban and industrial activity may be such as to tax the natural allowable waste-loading capacity of the waters. In those areas all of the reserve capacity to absorb wastes without detriment must sometimes be utilized.

Natural Purification Capacity of Water

In the preceding section it has been set forth that the allowable waste-loading capacity of waters may vary in a restrictive sense, i.e., in accordance with a policy of keeping wastes out, or of limiting the strength and amount of such discharges. The term is used in another and quite different sense to signify the capacity of waters for self-purification by natural agencies. This phenomenon which occurs in both surface and underground waters is discussed in the following paragraphs.

Surface Waters. The ability of a stream to purge itself of impurities is traditional, and has found expression in such folklore as "running water purifies itself in seven miles." Only in recent years, however, has a close study been made of the actions involved.

The mere presence of abnormal amounts of suspended matter, however stable and inert, can cause a condition of pollution or nuisance. Thus, such wastes as sawdust, clay, silt, chemical sludges, and waste oils render rivers and their banks unsightly, destroy fish, and impair water quality for domestic supply, irrigation, industrial use, and recreation. Prolonged silting may render navigation channels useless. The capacity of natural waters to accept waste loadings depends on many factors, including volume and transporting power. Large volumes of water reduce color, turbidity, and the toxic and irritant effects of wastes simply by diluting to concentrations where they are harmless and unnoticeable. Swiftly flowing waters may comminute and disperse suspended matter and remove it to areas where further dilution can render it harmless.

One of the most striking aspects of natural purification is bacterial self-purification. Contrary to popular impression, this effect is not confined to running water; indeed, it is usually more pronounced in bodies of standing water than in streams. Rapid and very high bacterial death rates are often observed. The explanation of this phenomenon is rather complicated but appears to lie fundamentally in the removal of the organisms to an alien and unfavorable environment outside the body of their host.

A third aspect of self-purification of natural waters is their capacity for biochemical self-purification. The significance of dissolved oxygen in stabilizing putrescible organic wastes has been discussed briefly heretofore. This consumption of oxygen constitutes a drain upon the oxygen resources of a stream, and if no natural compensating factors were at work, pollution problems would be aggravated enormously. In fact, however, nature works constantly to restore the oxygen balance of waters to normal.

The agencies of this restoration, (or reaeration) are complex. Under the influence of sunlight, green plants growing in water produce and release oxygen in such quantities that they may actually cause supersaturation. This phenomenon is restricted to the hours of daylight. Hence it may happen that a water supersaturated by day may lose all oxygen during the hours of night. Other factors affecting reaeration are solution by surface contact, diffusion from points of higher concentration of oxygen, and mixing by waves, winds, tidal currents, and turbulent flow. Mathematical expression of the phenomenon is possible, and for any given stream oxygen balance can be calculated with fair accuracy once the characteristics of that stream have been determined by field study.

Ground Waters. Natural processes of purification which prevail in the surface may be present below ground in weaker form, or perhaps be totally absent. Sunlight and air are lacking, plant and animal life exist in the top soil layers, turbulent flow is rare, and dilution is a much slower process.

The problem of gross organic pollution of subsurface waters is rarely met, largely because of inherent difficulties in introducing large quantities of common organic wastes below ground. Cesspools, recharge wells, and surface spreading grounds all tend to remove suspended solids by infiltration and bacteria and colloidal matter by biological action. It is possible, by massive application of sewage, to introduce bacteria below ground in considerable numbers. Several factors, however, are present to limit both their range and survival in homogeneous soils.

Pollution of ground water by substances in solution is more serious. Solutions of inorganic acids, bases, and salts, and organic liquids and solutions such as many industries employ, can pass readily into the soil, and once introduced are difficult to remove or neutralize. Natural dilution tends to be slow; artificial flushing is usually difficult and expensive; and treatment of the water is generally impracticable. The effects of such pollution may be long-lasting or permanent. Lateral and vertical diffusion of materials introduced into the ground water body may be very slow, resulting in a zone of high concentration downstream from the point of discharge. Efforts must be directed, therefore, toward excluding from ground water such wastes in harmful quantities, in order that the tremendous underground storage capacity is not destroyed by unwise or wasteful disposal practices.

QUALITY ASPECTS IN PLANNING FOR WATER PROJECTS

Protection of sources of water supplies from deterioration to the extent that their waters are rendered unusable for the beneficial purposes to which they must be put is a continuing consideration in California. Planning activities necessary to the development of additional water supplies and maintenance of the quality of existing supplies must provide for adequate disposal of wastes. This may entail the use of the dilution capacity of natural streams and of natural or artificial water bodies, the planned disposal of wastes in areas not contributing to usable water supplies, the provision of separate drainage facilities and ultimate disposal in the ocean or bays, or other feasible methods of preventing adverse effect on usable water supplies. These problems are being considered in the formulation of The California Water Plan, and, to the extent necessary to provide for the full development and utilization of the State's water resources, physical solution will be incorporated in the plan.

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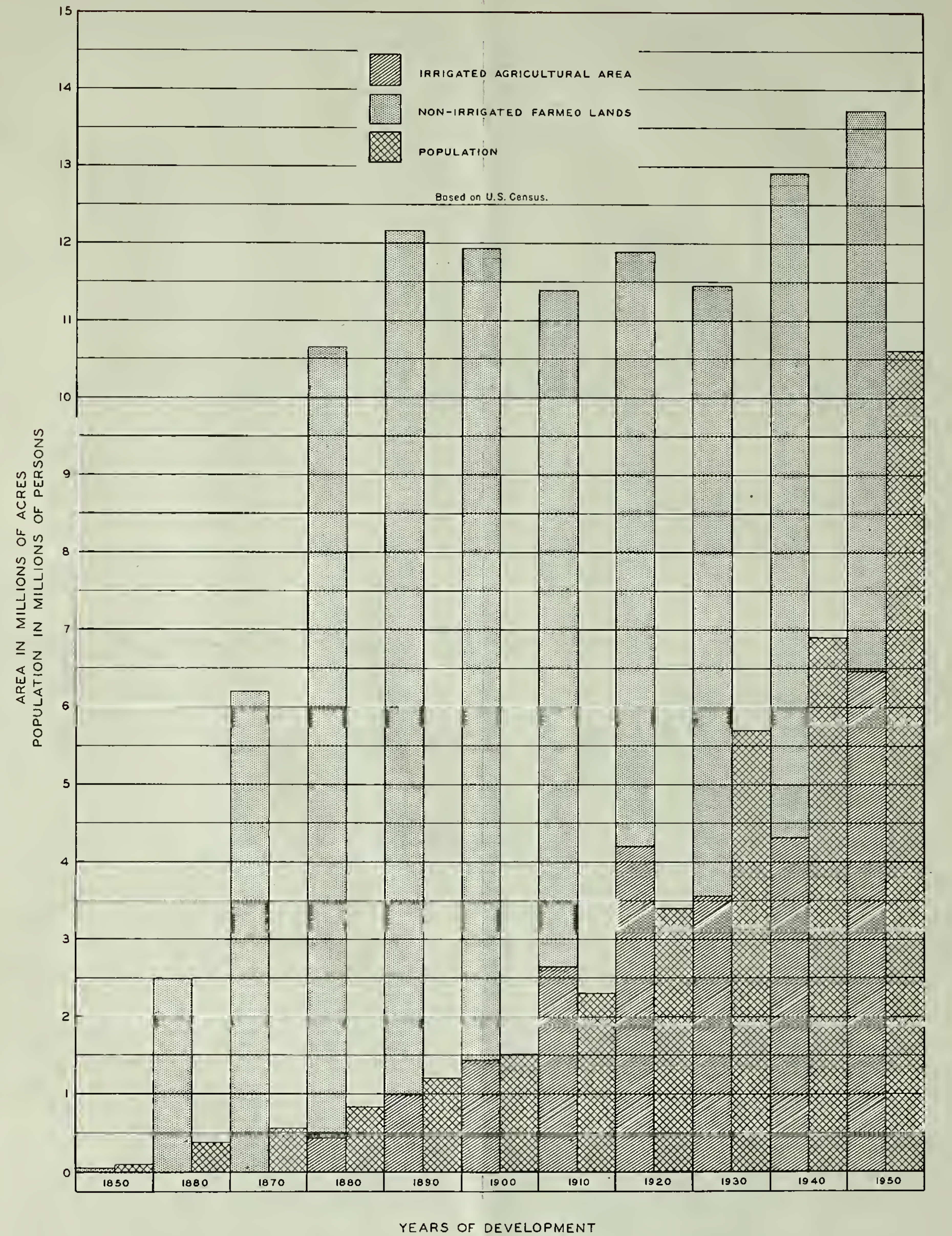
LEGEND
IRRIGATED AREA 1946 - 1953 (See text)
POTENTIAL IRRIGATED AND URBAN AREAS
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
COLORADO
RIVER
Salton Sea
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
LAKE
COLUSA
SUTTER
YUBA
NEVADA
PLACER
YOLO
SONOMA
NAPA
MARIN
SOLANO
SACRAMENTO
EL DORADO
AMADOR
ALPINE
CALAVERAS
TUOLUMNE
MONO
MARIPOSA
MADERA
FRESNO
INYO
MERCED
STANISLAUS
SAN JOAQUIN
CONTRA COSTA
ALAMEDA
SAN MATEO
SANTA CLARA
SANTA CRUZ
SAN BENITO
MONTEREY
KINGS
TULARE
KERN
SAN LUIS OBISPO
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
RIVERSIDE
ORANGE
SAN DIEGO
IMPERIAL
SAN FRANCISCO
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
WATER SERVICE AREAS
FOR
THE CALIFORNIA WATER PLAN
SCALE OF MILES
10 0 10 20 30 40 50



GROWTH OF POPULATION AND CULTIVATED AND IRRIGATED LANDS OF CALIFORNIA

DIVISION OF WATER RESOURCES


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
IRRIGATION AND WATER STORAGE DISTRICTS
1954
SCALE OF MILES
PACIFIC OCEAN
OREGON
NEVADA
ARIZONA
MEXICO
COLORADO RIVER AQUEDUCT
ALL AMERICAN CANAL
Salton Sea
Lake Tahoe
Mono Lake
Shasta Reservoir


LEGEND
DRAINAGE AREA BOUNDARY
NORTH COASTAL AREA
SAN FRANCISCO BAY AREA
CENTRAL COASTAL AREA
SOUTH COASTAL AREA
CENTRAL VALLEY AREA
LAHONTAN AREA
COLORADO DESERT AREA
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
BUTTE
GLENN
COLUSA
SUTTER
YUBA
SIERRA
NEVADA
PLACER
EL DORADO
AMADOR
ALPINE
CALAVERAS
TUOLUMNE
MONO
MARIPOSA
MADERA
FRESNO
INYO
TULARE
KINGS
KERN
SAN BERNARDINO
RIVERSIDE
IMPERIAL
SAN DIEGO
ORANGE
LOS ANGELES
VENTURA
SANTA BARBARA
SAN LUIS OBISPO
MONTEREY
SAN BENITO
MERCED
STANISLAUS
SAN JOAQUIN
SACRAMENTO
YOLO
LAKE
MENDOCINO
SONOMA
NAPA
SOLANO
MARIN
CONTRA COSTA
ALAMEDA
SANTA CLARA
SANTA CRUZ
SAN MATEO
SAN FRANCISCO
Crescent City
Eureka
Yreka
Weaverville
Redding
Red Bluff
Alturas
Susanville
Quincy
Oroville
Willows
Colusa
Marysville
Yuba City
Auburn
Sacramento
Placerville
Woodland
Fairfield
Napa
Santa Rosa
San Rafael
Oakland
Martinez
Stockton
Modesto
Merced
Mariposa
Madera
Fresno
Visalia
Hanford
Bakersfield
Independence
Bridgeport
Salinas
Hollister
San Luis Obispo
Santa Barbara
Ventura
Riverside
San Bernardino
Santa Ana
San Diego
El Centro
Salton Sea
Tulare Lake
Buena Vista Lake
Owens Lake
Mono Lake
Lake Tahoe
Clear Lake
Goose Lake
Shasta Reservoir
COLORADO
RIVER
SACRAMENTO RIVER
SAN JOAQUIN
KLAMATH
Eel
Russian River
Salinas River
Kern River
Mojave River
Owens River
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
VALLEY FILL AREAS
1953
SCALE OF MILES
10 0 10 20 30 40 50


LEGEND
GENERATING STATIONS
HYDRO
FUEL
UNDER CONSTRUCTION
EXISTING
PUBLICLY OWNED (NON FEDERAL)
PUBLICLY OWNED (FEDERAL)
PRIVATELY OWNED
CAPACITY BASED ON NAME PLATE RATING
100,000 KILOWATTS AND OVER
50,000 TO 100,000 KILOWATTS
15,000 TO 50,000 KILOWATTS
1,000 TO 15,000 KILOWATTS
TRANSMISSION SUBSTATIONS
TRANSMISSION SUBSTATION WHERE CHANGES OF VOLTAGE ARE SHOWN
NOTE- STEP UP SUBSTATIONS AT GENERATING PLANTS NOT INDICATED BY SEPERATE SYMBOL
DISTRIBUTION SUBSTATION - OMITTED WHEN IT COINCIDES WITH A COMMUNITY
TRANSMISSION LINES
WHERE TWO NUMBERS OCCUR (VIZ: 44/110) THE FIRST NUMBER INDICATES OPERATING VOLTAGE AND THE SECOND NUMBER INDICATES INSULATED OR DESIGN VOLTAGE.
LINES LESS THAN 22 KV INDICATED IN SPECIAL CASES ONLY NOMINAL OPERATING VOLTAGES INDICATED IN THOUSANDS OF VOLTS
22 EXISTING 22 UNDER CONSTRUCTION 11 UNDERGROUND
189,000 VOLT CIRCUIT AND OVER
100,000 TO 154,000 VOLT CIRCUIT
55,000 TO 88,000 VOLT CIRCUIT
22,000 TO 50,000 VOLT CIRCUIT
33C CIRCUITS OTHER THAN 60 CYCLE FREQUENCY INDICATED
INTERCONNECTION BETWEEN AFFILIATED COMPANIES
INTERCONNECTION BETWEEN NON-AFFILIATED COMPANIES
TRANSMISSION LINE OF ONE COMPANY CROSSING STATE BOUNDARY (SEPARATE OWNERSHIP NUMBERS REFER TO EACH STATE)
COMMUNITIES
OR 25,000 POPULATION AND OVER
10,000 TO 25,000 POPULATION
LESS THAN 10,000 POPULATION
Reprinted with minor deletions from Regional Transmission Map No.11, 1954, of the Federal Power Commission.
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
ELECTRIC POWER DEVELOPMENT
1954
SCALE OF MILES
10 0 10 20 30 40 50
OREGON
NEVADA
CALIFORNIA
ARIZONA
CALIFORNIA
MEXICO
PACIFIC OCEAN
HOOVER DAM
PARKER DAM
SALTON SEA
BIG CREEK INSERT
SAN FRANCISCO AND VICINITY
LOS ANGELES AND VICINITY
SAN BERNARDINO AND VICINITY
Between San Francisco and Sacramento, transmission lines less than 66 KV are omitted


LEGEND
TIMBER LANDS
AURIFEROUS GRAVELS
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
COLORADO RIVER
Lake Havasu
Salton Sea
Owens Lake
Mono Lake
Tulare Lake
Buena Vista Lake
DEL NORTE
SISKIYOU
MODOC
HUMBOLDT
TRINITY
SHASTA
LASSEN
TEHAMA
PLUMAS
GLENN
BUTTE
SIERRA
MENDOCINO
COLUSA
SUTTER
YUBA
NEVADA
PLACER
LAKE
YOLO
SONOMA
NAPA
SOLANO
SACRAMENTO
EL DORADO
AMADOR
ALPINE
CALAVERAS
SAN JOAQUIN
MARIN
CONTRA COSTA
ALAMEDA
SAN FRANCISCO
SAN MATEO
SANTA CLARA
SANTA CRUZ
STANISLAUS
TUOLUMNE
MONO
MARIPOSA
MERCED
MADERA
FRESNO
SAN BENITO
MONTEREY
INYO
KINGS
TULARE
SAN LUIS OBISPO
KERN
SANTA BARBARA
VENTURA
LOS ANGELES
SAN BERNARDINO
ORANGE
RIVERSIDE
SAN DIEGO
IMPERIAL
Sacramento
San Francisco
Oakland
Stockton
Fresno
Bakersfield
Los Angeles
San Diego
Santa Barbara
Ventura
Riverside
San Bernardino
El Centro
Merced
Modesto
Madera
Hanford
Visalia
Independence
Bridgeport
Marysville
Oroville
Red Bluff
Redding
Weaverville
Eureka
Ukiah
Santa Rosa
Napa
Fairfield
Martinez
Woodland
Colusa
Willows
Auburn
Placerville
Jackson
San Jose
Hollister
Salinas
San Luis Obispo
Santa Ana
Mariposa
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
TIMBER LANDS
AND
AURIFEROUS GRAVEL DEPOSITS
SCALE OF MILES
10 0 10 20 30 40 50


LEGEND
STATE PARK - 1953
NATIONAL FOREST
NATIONAL PARK OR MONUMENT
WILDERNESS AREA
STATE WATERFOWL MANAGEMENT AREA
FEDERAL WATERFOWL REFUGE
WATERFOWL MIGRATION ROUTE
FISH HATCHERY
Historical monuments not shown
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
RECREATIONAL AREAS
SCALE OF MILES
10 0 10 20 30 40 50

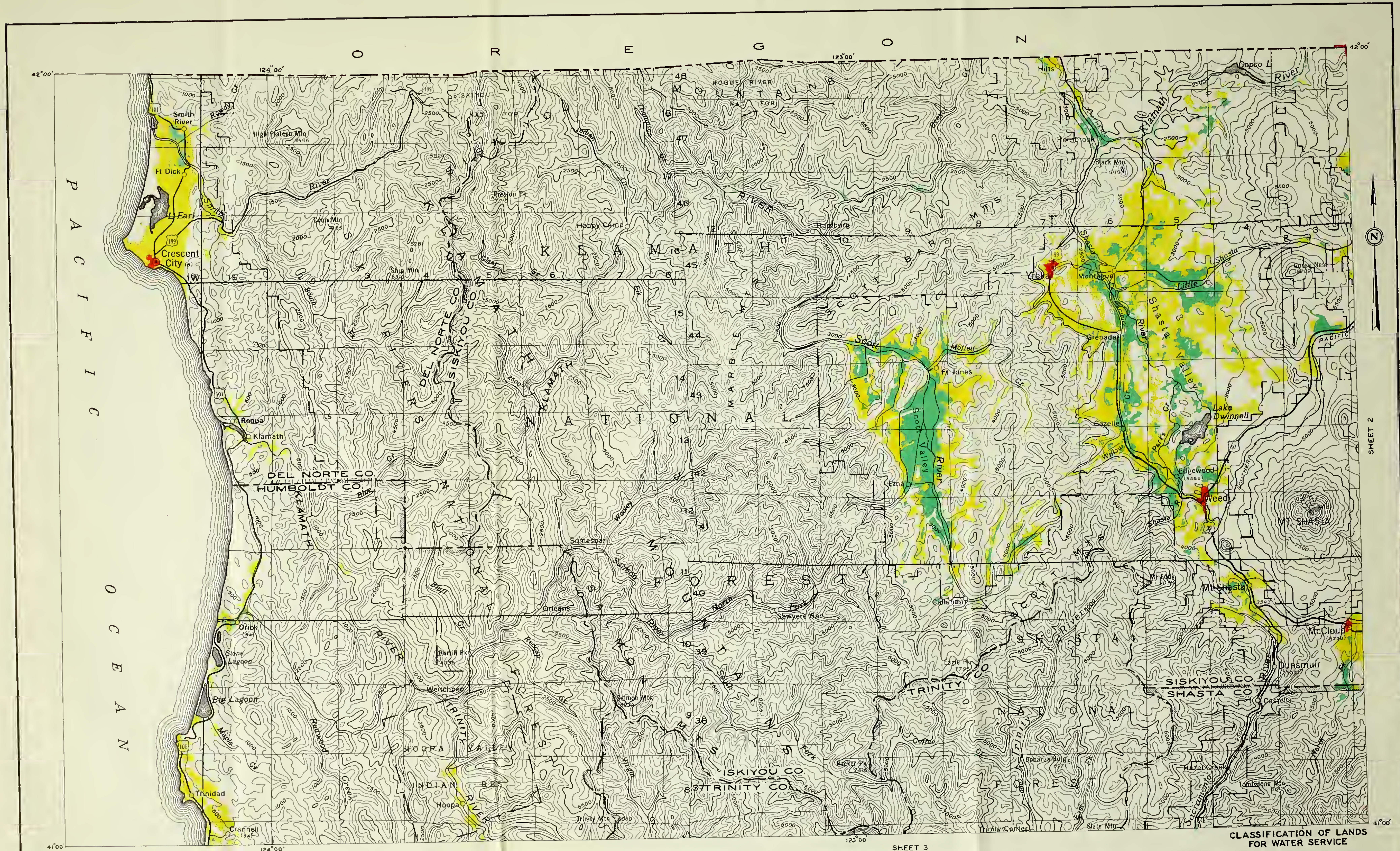
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

MAJOR HYDROGRAPHIC AREAS AND HYDROGRAPHIC UNITS

1953

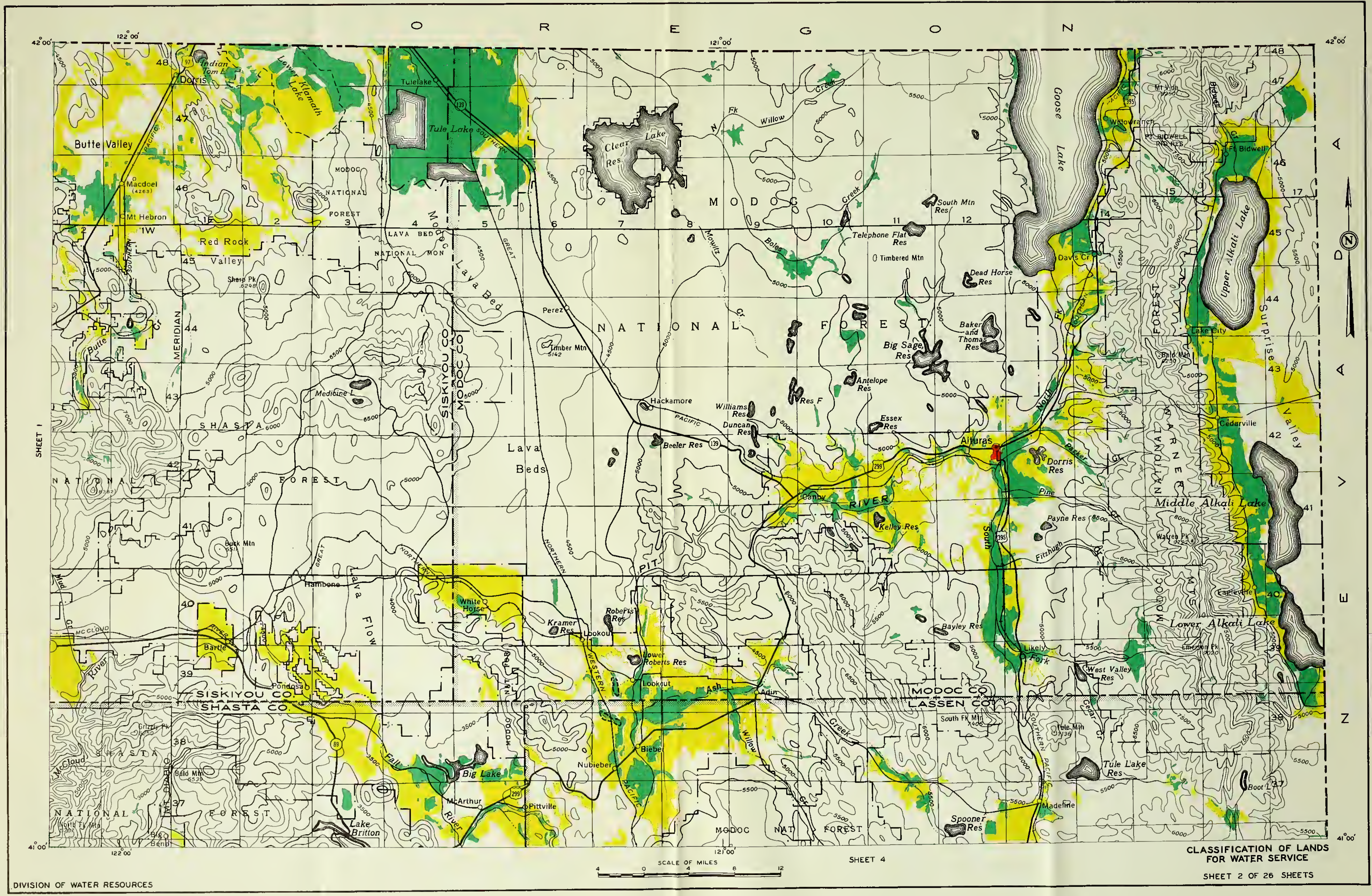
PLATE 9

LEGEND
URBAN AREA
IRRIGATED AREA 1946-1953 (See Text)
POTENTIAL URBAN OR IRRIGATED AREA
MILITARY AREA
TIDE LANDS SUSCEPTIBLE OF RECLAMATION
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
CLASSIFICATION OF LANDS
FOR WATER SERVICE
FROM
THE CALIFORNIA WATER PLAN
INDEX TO SHEETS
SCALE OF MILES
20 0 20 40 60
OREGON
NEVADA
ARIZONA
MEXICO
PACIFIC OCEAN
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26

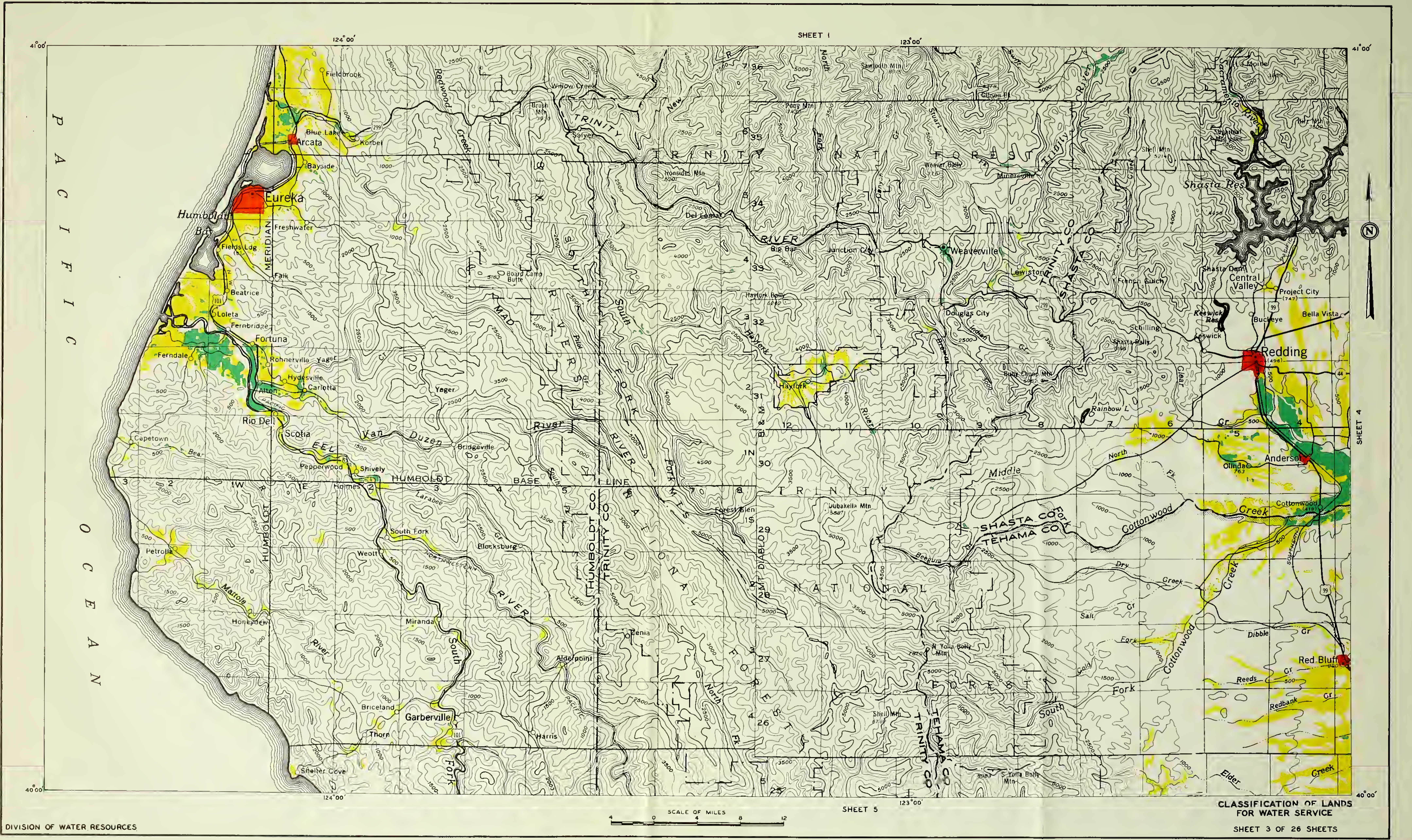


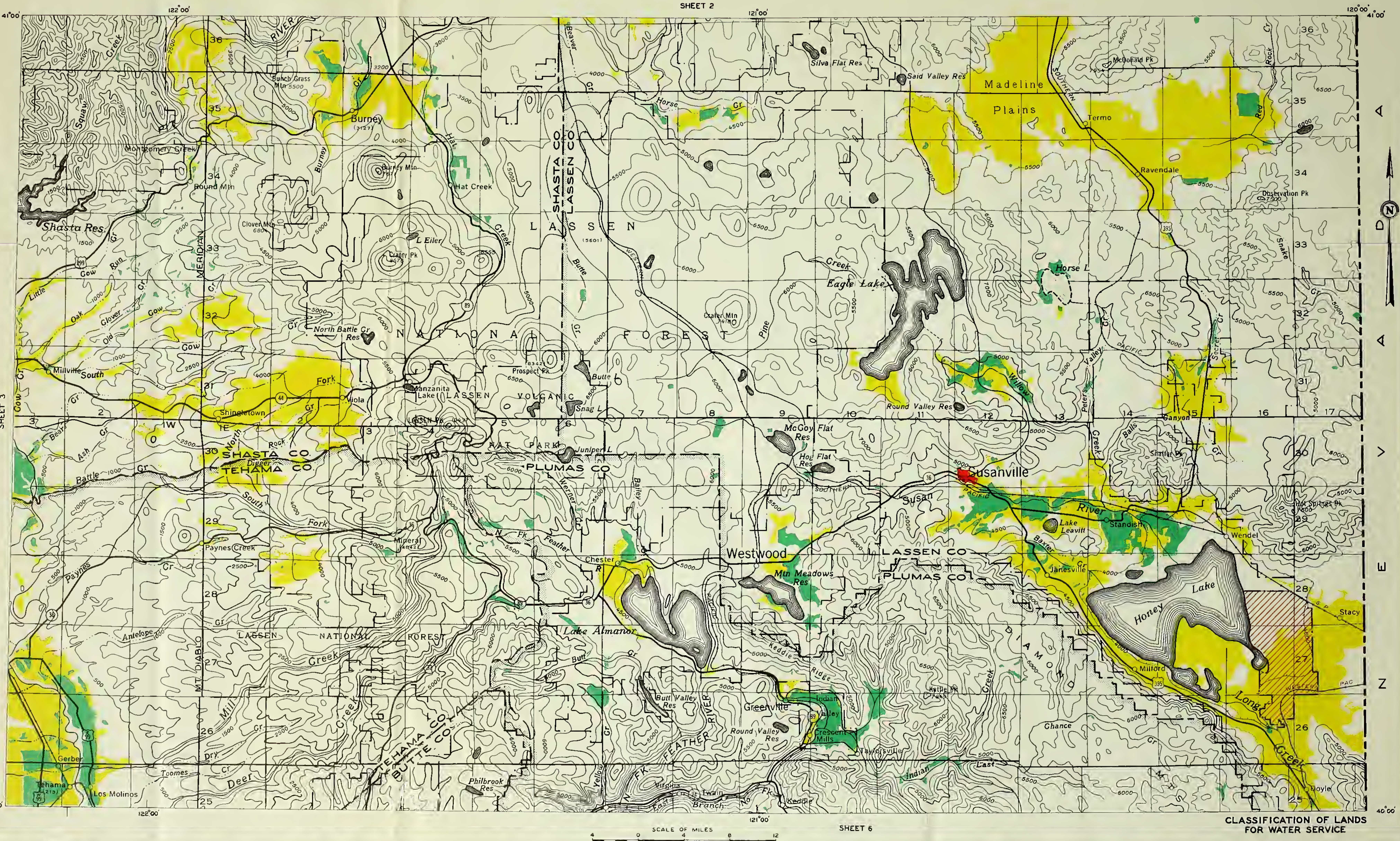
CLASSIFICATION OF LANDS FOR WATER SERVICE
SHEET 1 OF 26 SHEETS

DIVISION OF WATER RESOURCES



O R E G O N
N E V A D A
122°00'
121°00'
42°00'
41°00'
Butte Valley
Doris
Macdoel
Mt Hebron
Red Rock Valley
Shasta Pk
Lower Klamath Lake
Tulelake
Tule Lake
Clear Lake Res
MODOC NATIONAL FOREST
LAVA BED NATIONAL MON
Lava Beds
Perez
Timber Mtn
Medicine L
Hackamore
Williams Res
Duncan Res
Beeler Res
Res F
Antelope Res
Essex Res
Big Sage Res
Baker and Thomas Res
Dead Horse Res
Telephone Flat Res
Timbered Mtn
South Mtn Res
Goose Lake
Davis Cr
Willow Ranch
FT BIDWELL IND RES
Ft Bidwell
Upper Alkali Lake
Lake City
Surprise Valley
Cedarville
Middle Alkali Lake
Eagleville
Lower Alkali Lake
Alturas
Dorris Res
Payne Res
Canby
PIT RIVER
Kelley Res
North Fk
South Fk
Likely
West Valley Res
Bayley Res
SISKIYOU CO
MODOC CO
SHASTA CO
LASSEN CO
SHASTA NATIONAL FOREST
Buck Mtn
Hambone
Lava Flow
White Horse
Kramer Res
Lookout
Roberts Res
Lower Roberts Res
Adin
Ash Cr
Bartle
Pondosa
McCloud River
Grizzly Pk
Bald Mtn
Big Bend
Fall River
Big Lake
McArthur
Pittville
Lake Britton
Bieber
Nubieber
Willow Cr
South Fk Mtn
Tule Mtn
Tule Lake Res
Spooner Res
Madeline
Boot L
MODOC NAT FOREST
WARNER MODOC NATIONAL FOREST
Emerson Pk
Warren Pk
SHEET 1
SHEET 4
SCALE OF MILES
4 0 4 8 12
DIVISION OF WATER RESOURCES
CLASSIFICATION OF LANDS FOR WATER SERVICE
SHEET 2 OF 26 SHEETS

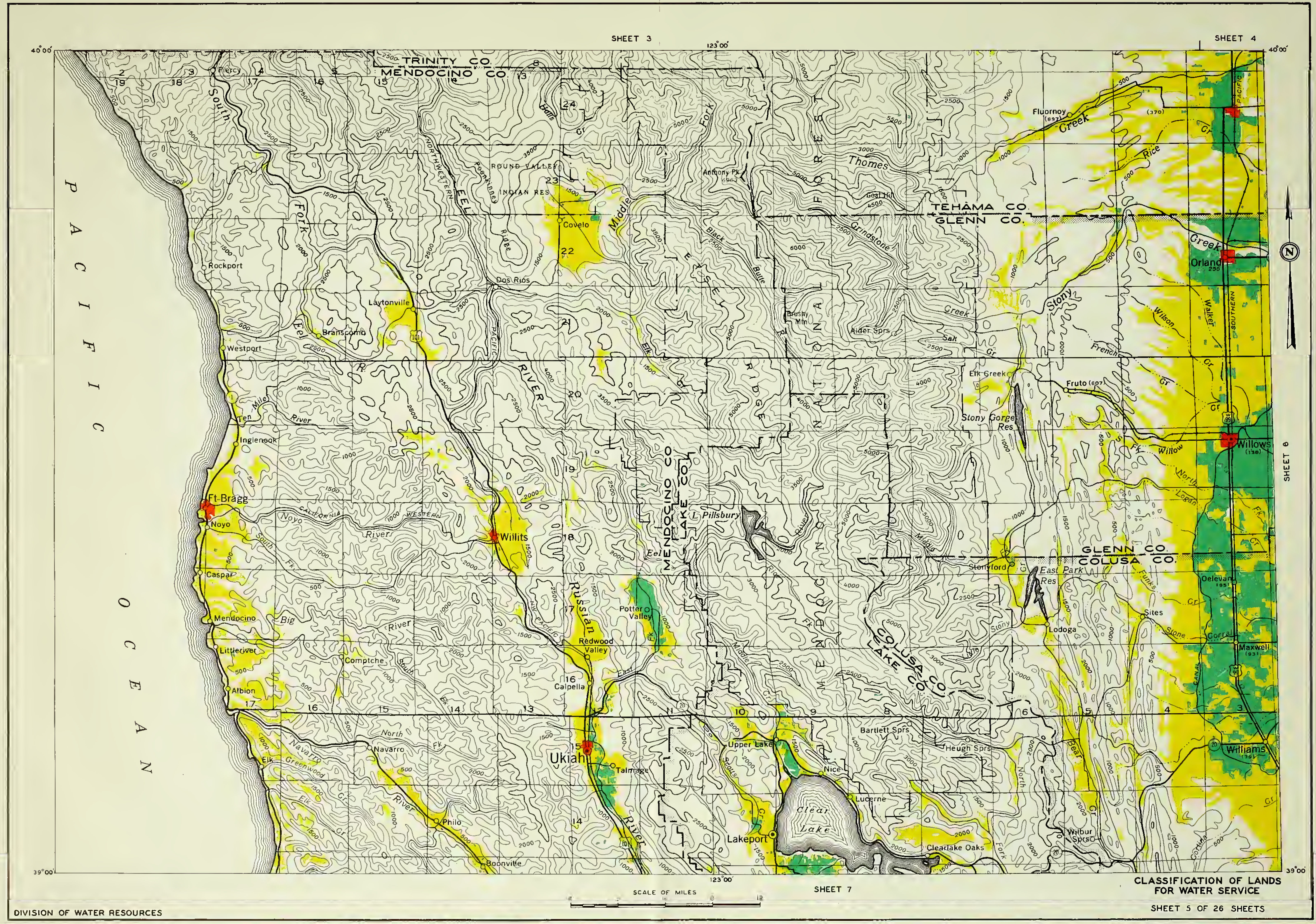

SHEET 1
SHEET 5
SHEET 4
PACIFIC OCEAN
Eureka
Arcata
Fortuna
Redding
Red Bluff
Anderson
Weaverville
Garberville
Shasta Res
HUMBOLDT BASE LINE
HUMBOLDT MERIDIAN
MT DIABLO MERIDIAN
TRINITY NATIONAL FOREST
SCALE OF MILES
4 0 4 8 12
DIVISION OF WATER RESOURCES
CLASSIFICATION OF LANDS
FOR WATER SERVICE
SHEET 3 OF 26 SHEETS



DIVISION OF WATER RESOURCES

CLASSIFICATION OF LANDS
FOR WATER SERVICE

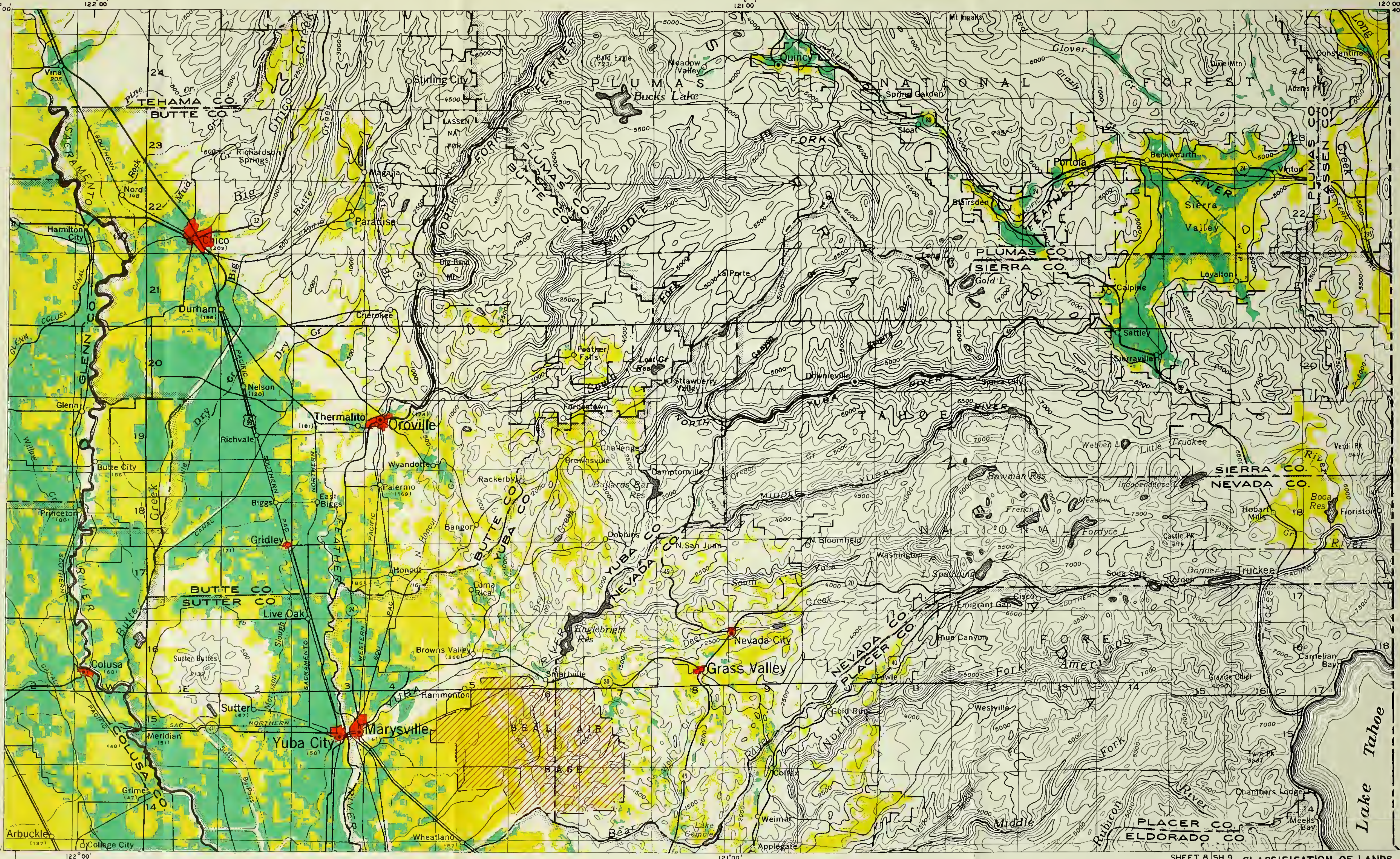
SHEET 4 OF 26 SHEETS



CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 5 OF 26 SHEETS

SHEET 4

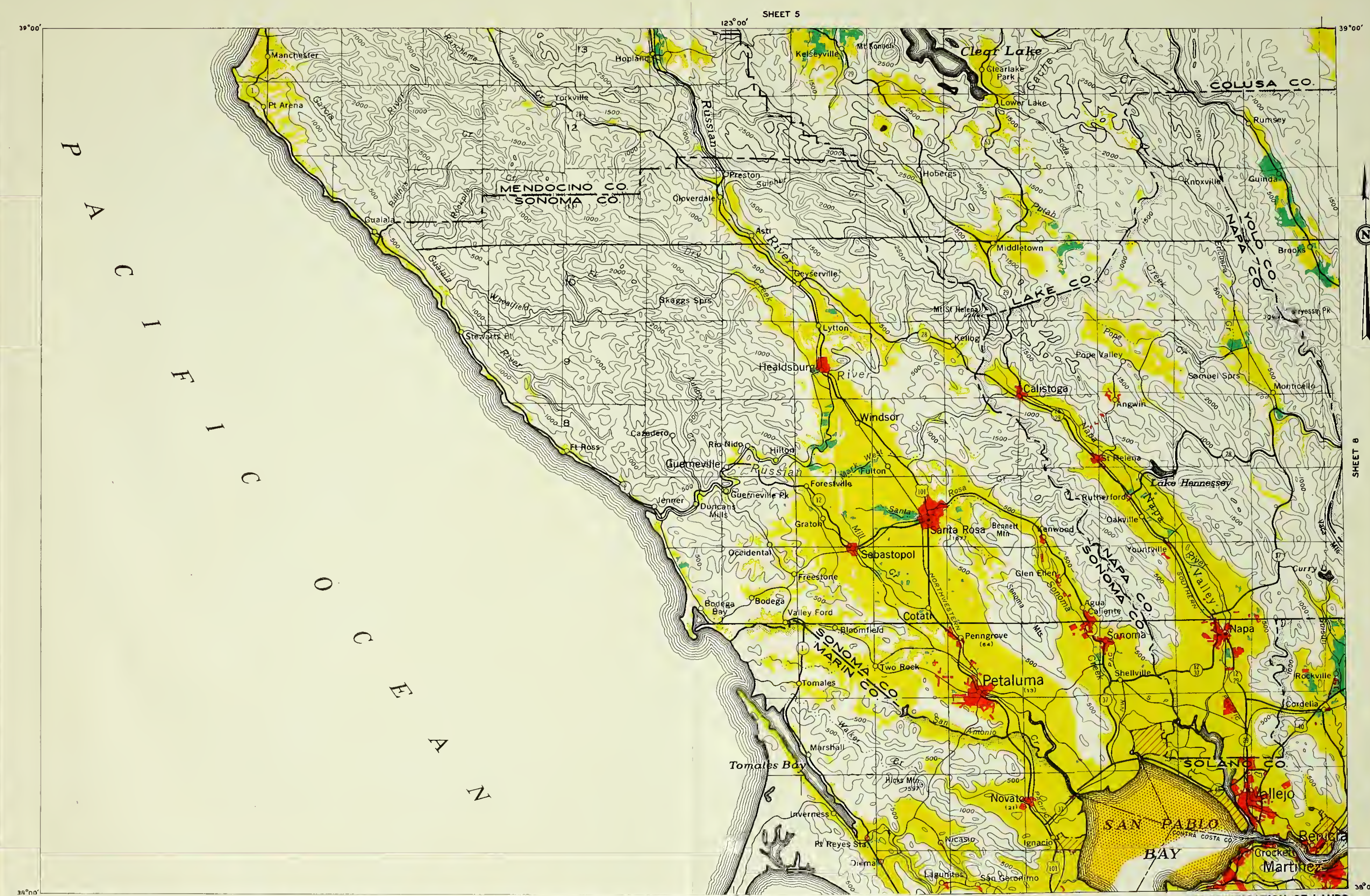


SHEET 8 | SH. 9

CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 6 OF 26 SHEETS

DIVISION OF WATER RESOURCES



SCALE OF MILES

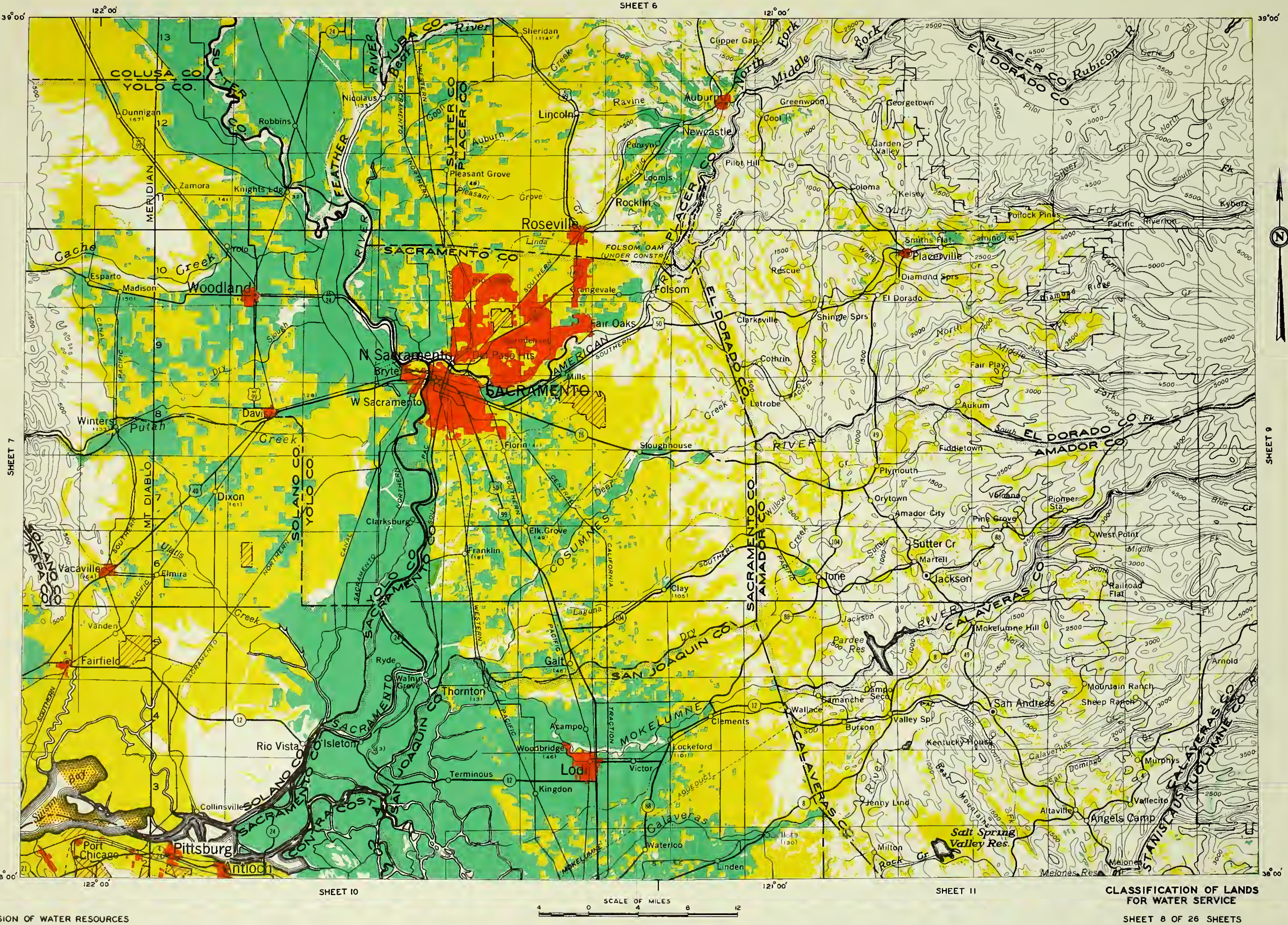
4 0 4 8 12

DIVISION OF WATER RESOURCES

CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 7 OF 26 SHEETS

SHEET 6



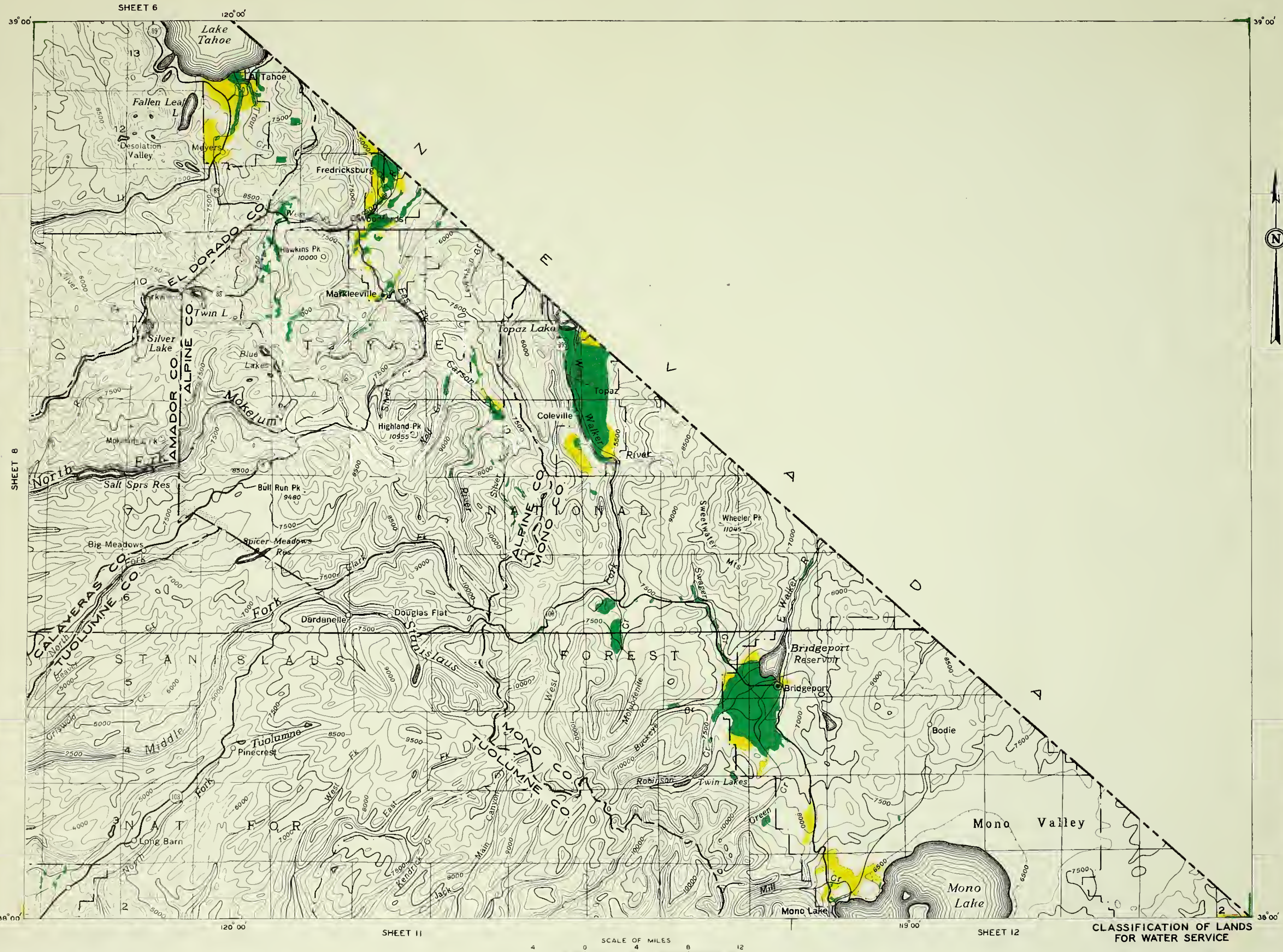
SHEET 7 SHEET 9

SHEET 10 SHEET 11

CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 8 OF 26 SHEETS

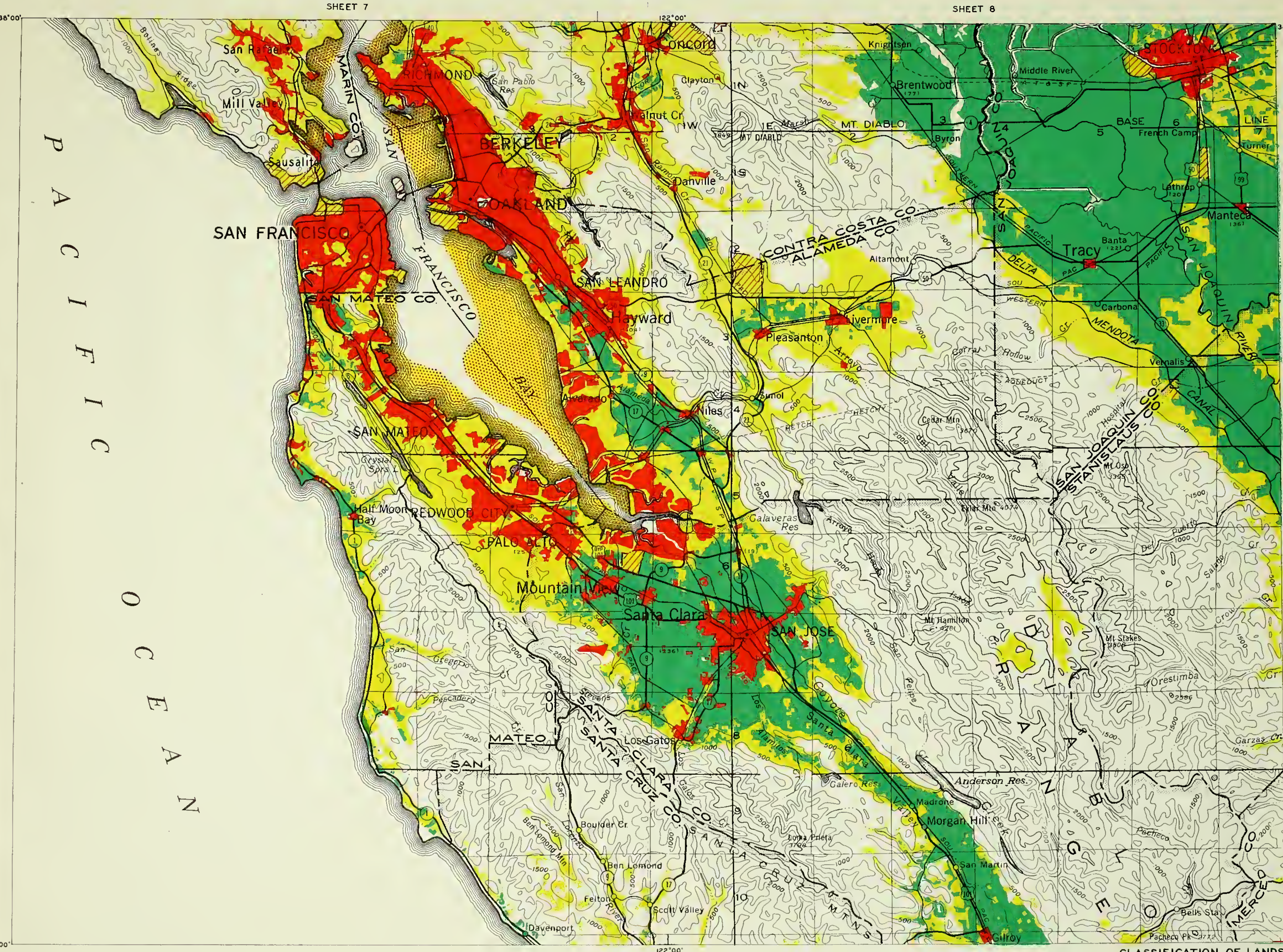
DIVISION OF WATER RESOURCES



CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 9 OF 26 SHEETS

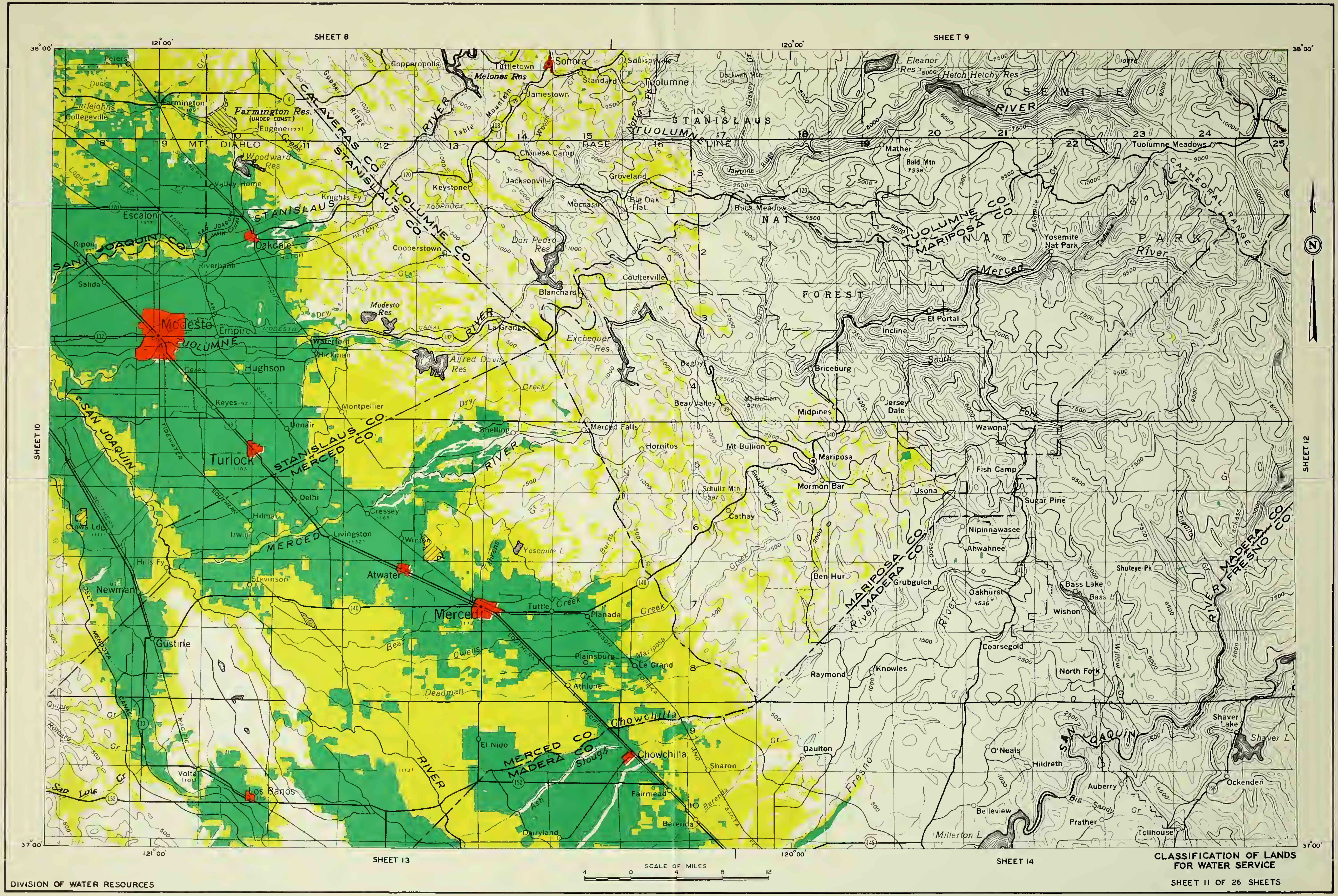
DIVISION OF WATER RESOURCES



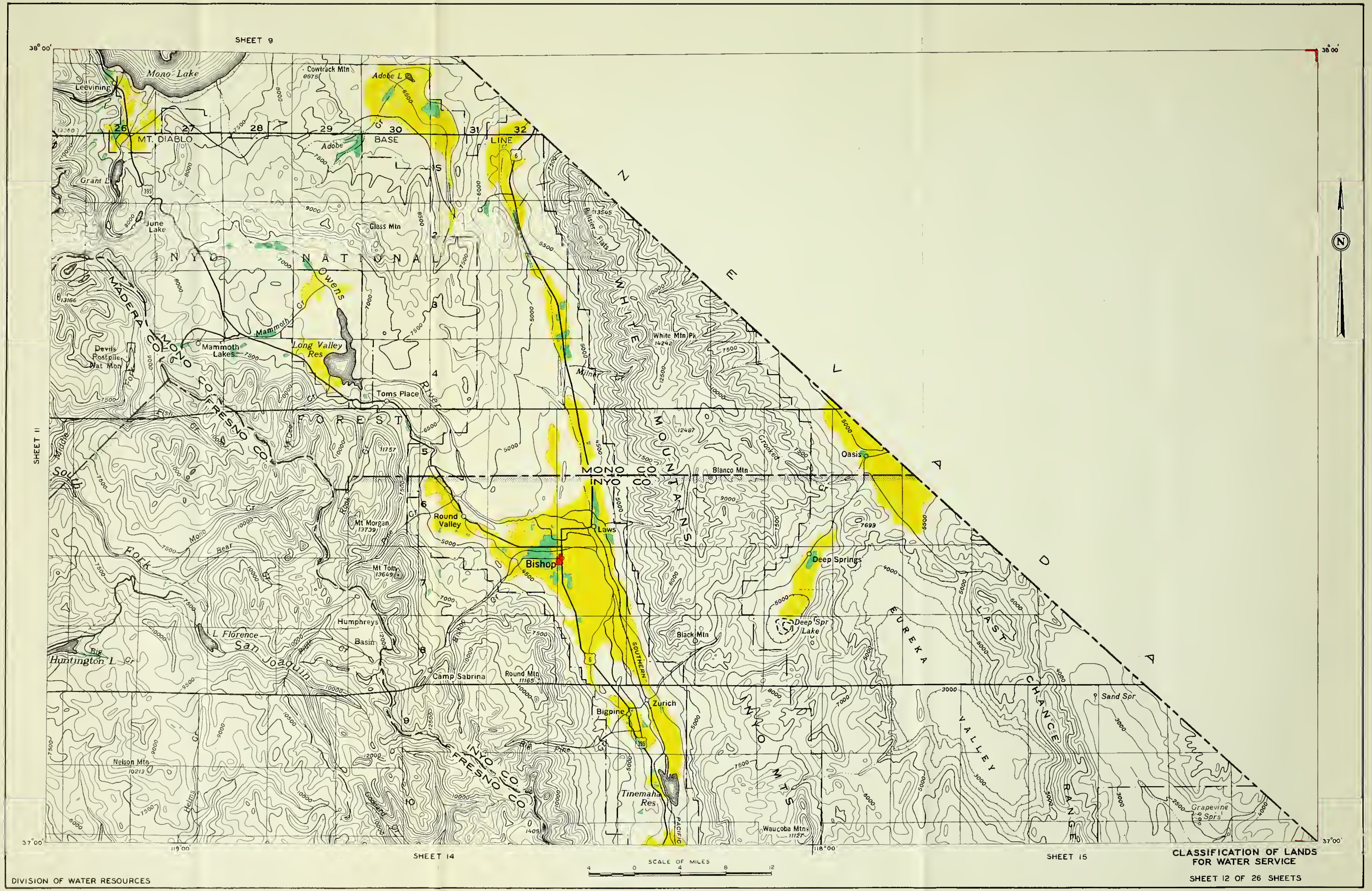
SCALE OF MILES

CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 10 OF 26 SHEETS



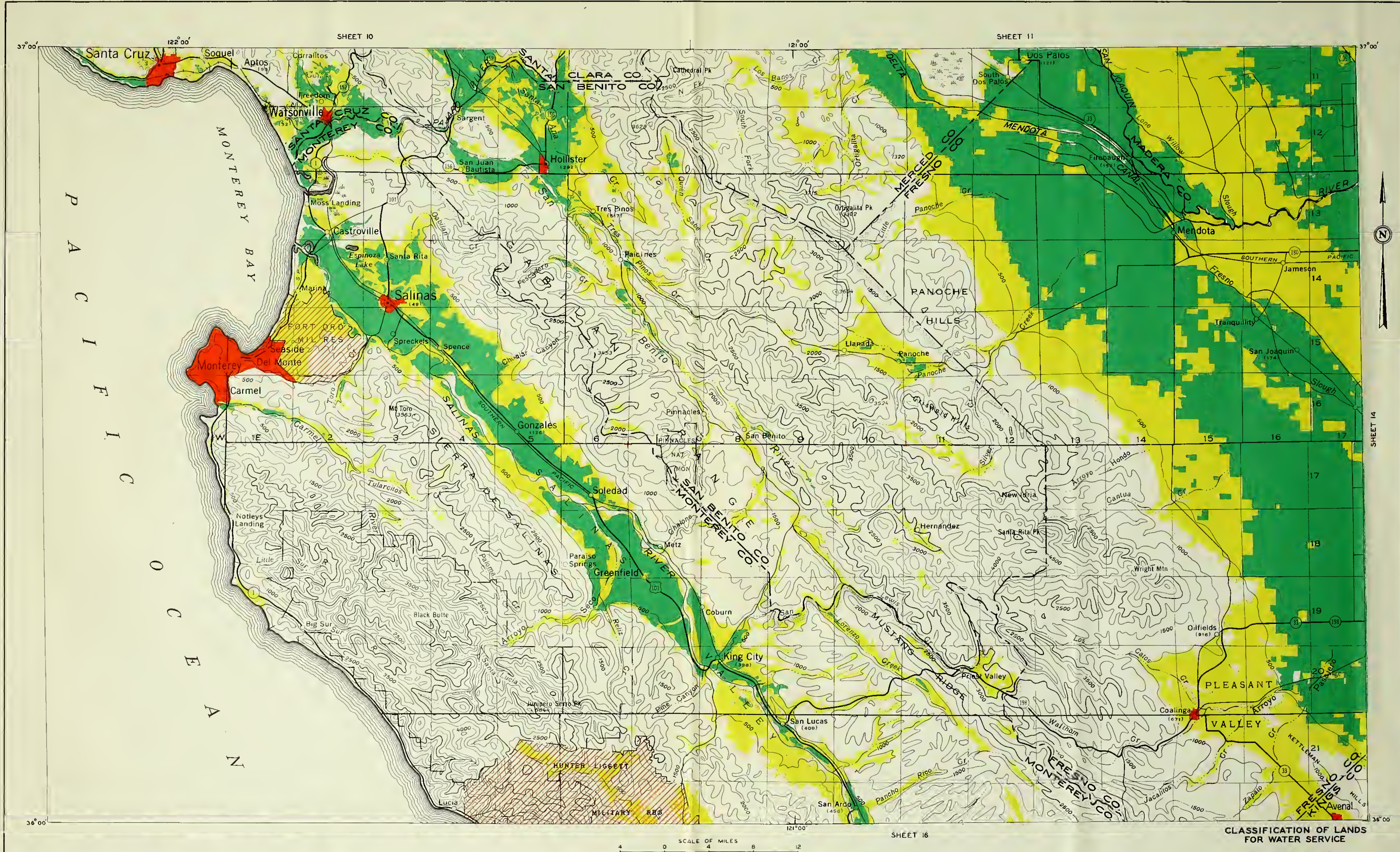
SHEET 8
SHEET 9
SHEET 10
SHEET 12
SHEET 13
SHEET 14
CLASSIFICATION OF LANDS
FOR WATER SERVICE
SHEET 11 OF 26 SHEETS
DIVISION OF WATER RESOURCES
SCALE OF MILES
Modesto
Turlock
Merced
Oakdale
Atwater
Chowchilla
Los Banos
Sonora
Mariposa
YOSEMITE
Farmington Res.
Don Pedro Res
Exchequer Res.
Hetch Hetchy Res



CLASSIFICATION OF LANDS FOR WATER SERVICE

DIVISION OF WATER RESOURCES

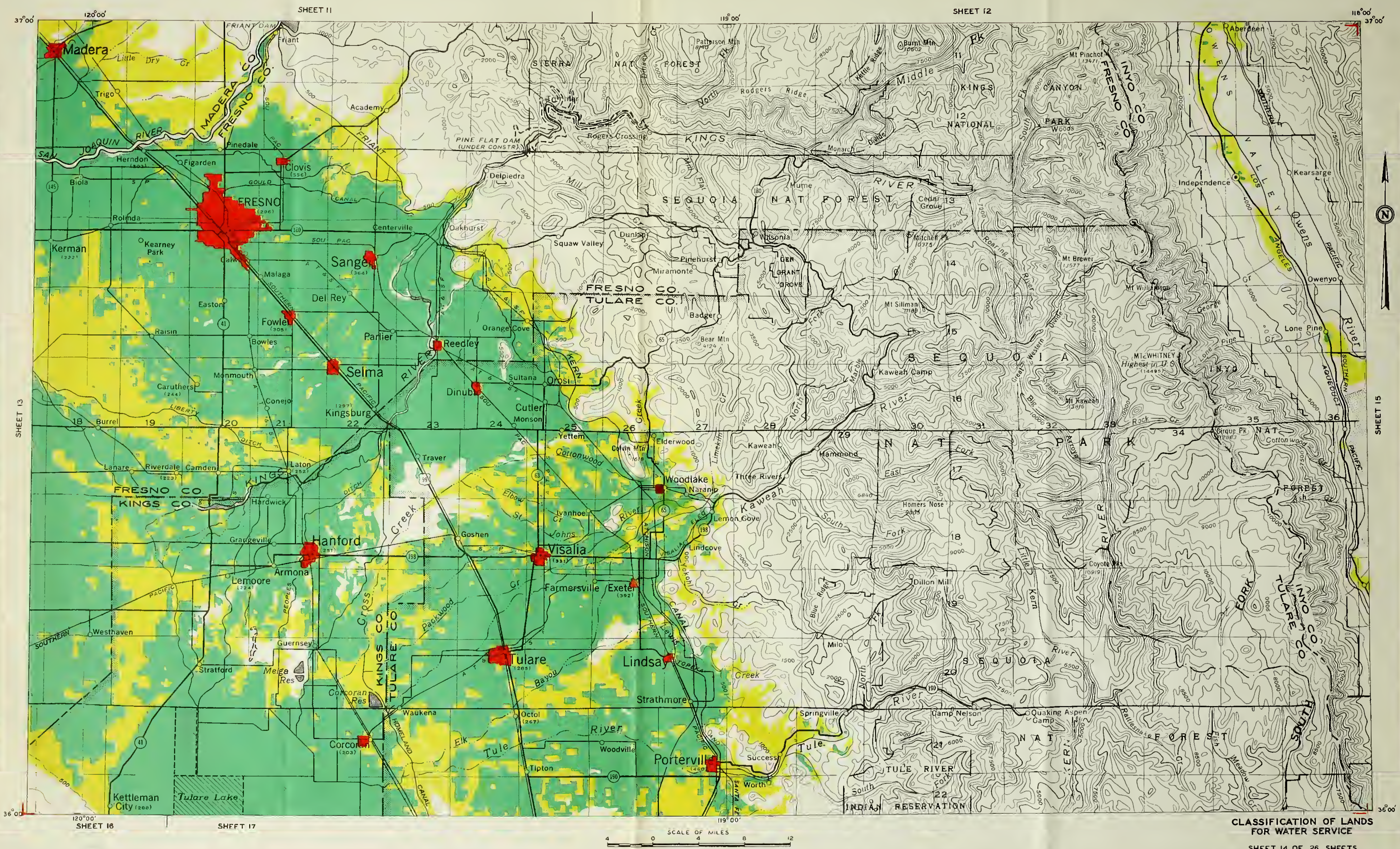
SHEET 12 OF 26 SHEETS



CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 13 OF 26 SHEETS

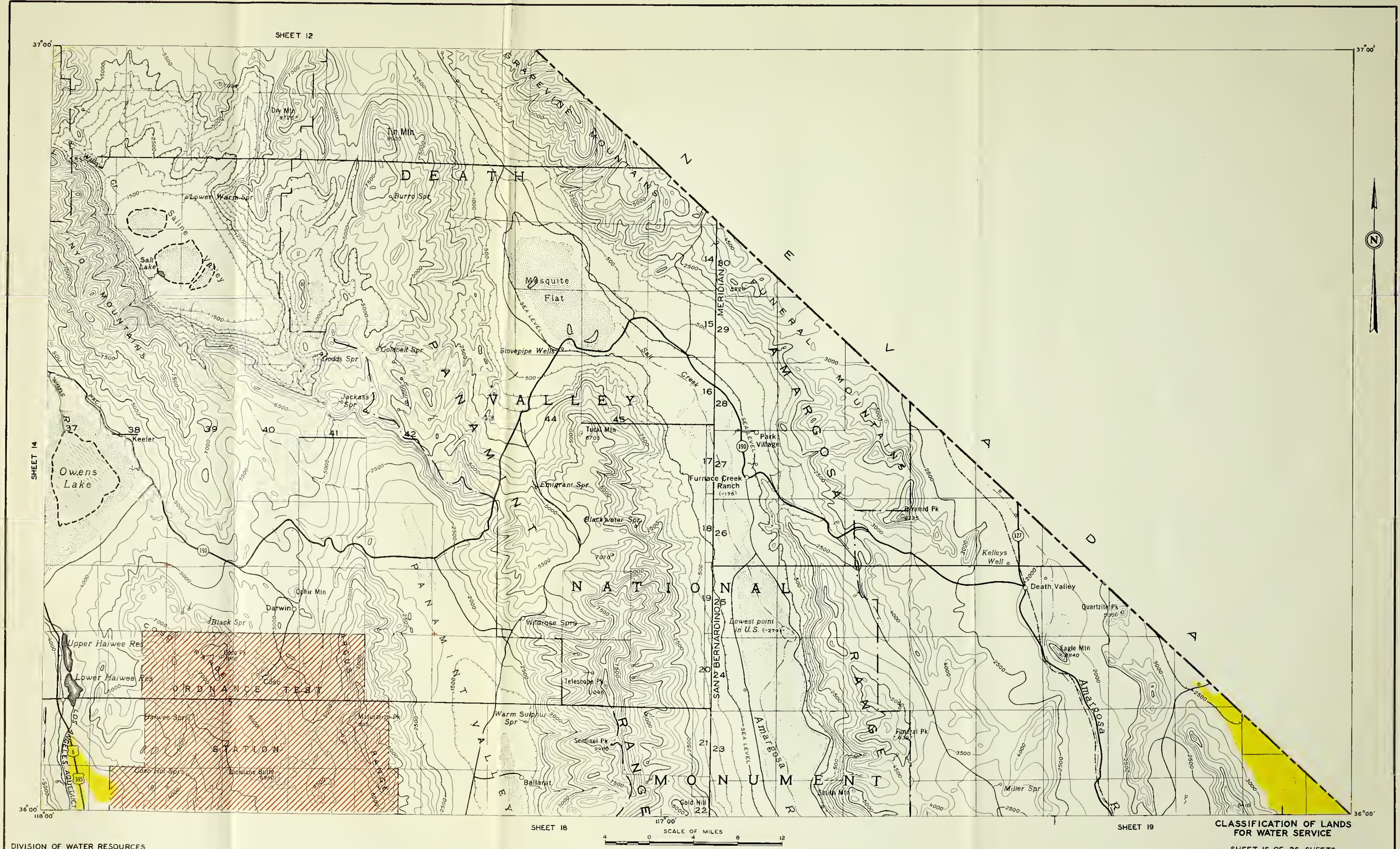
DIVISION OF WATER RESOURCES



CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 14 OF 26 SHEETS

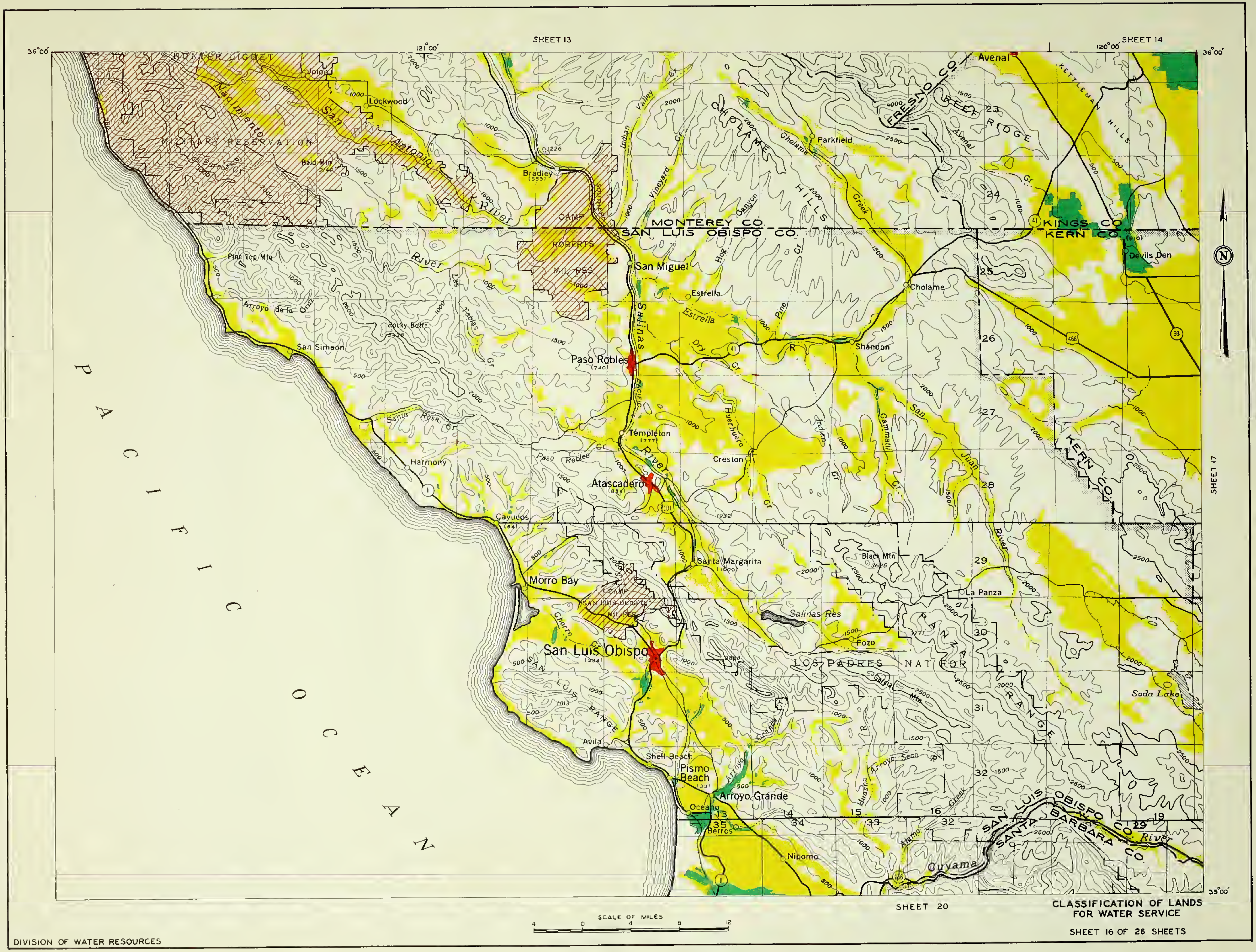
DIVISION OF WATER RESOURCES



CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 15 OF 26 SHEETS

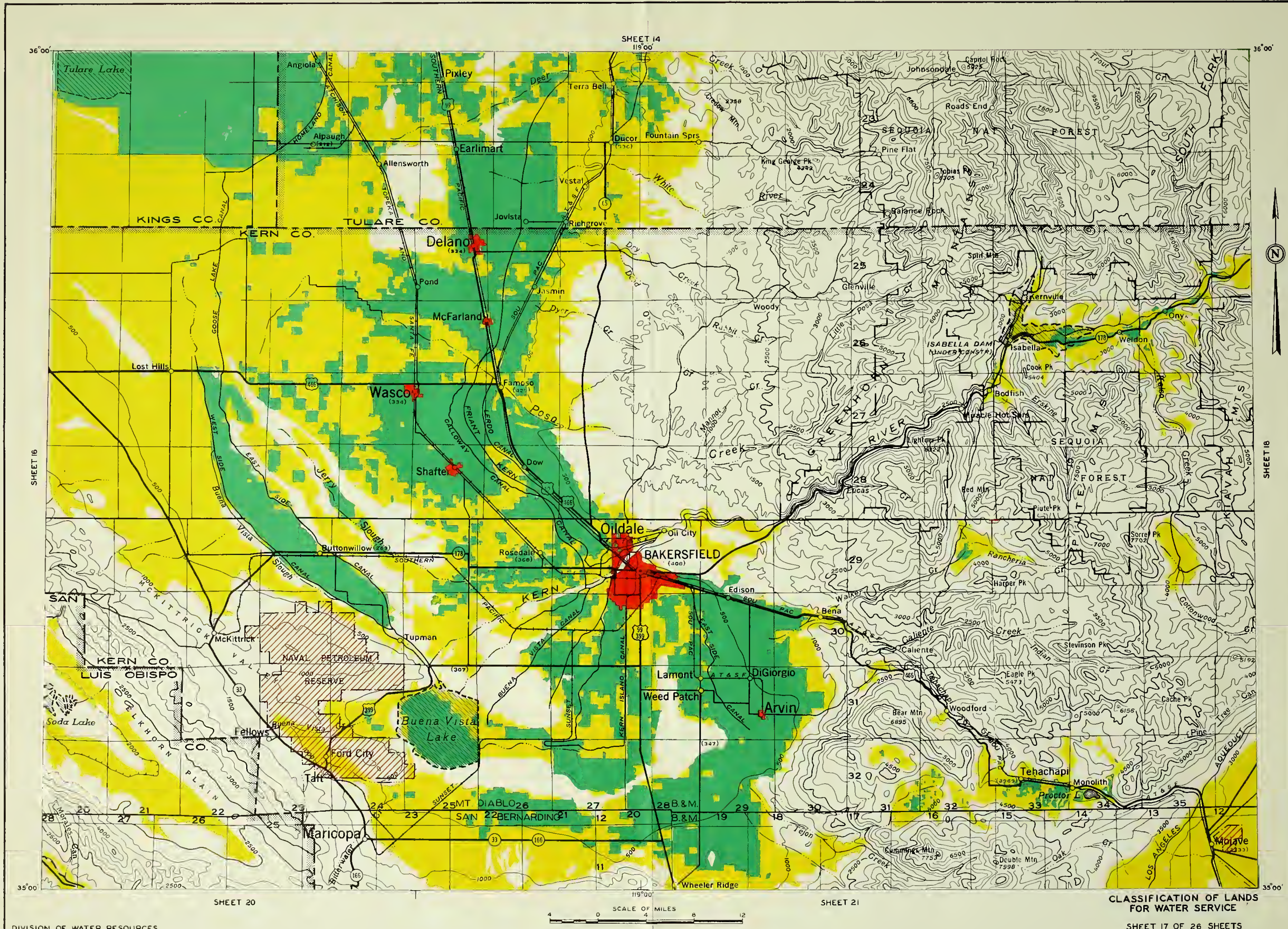
DIVISION OF WATER RESOURCES

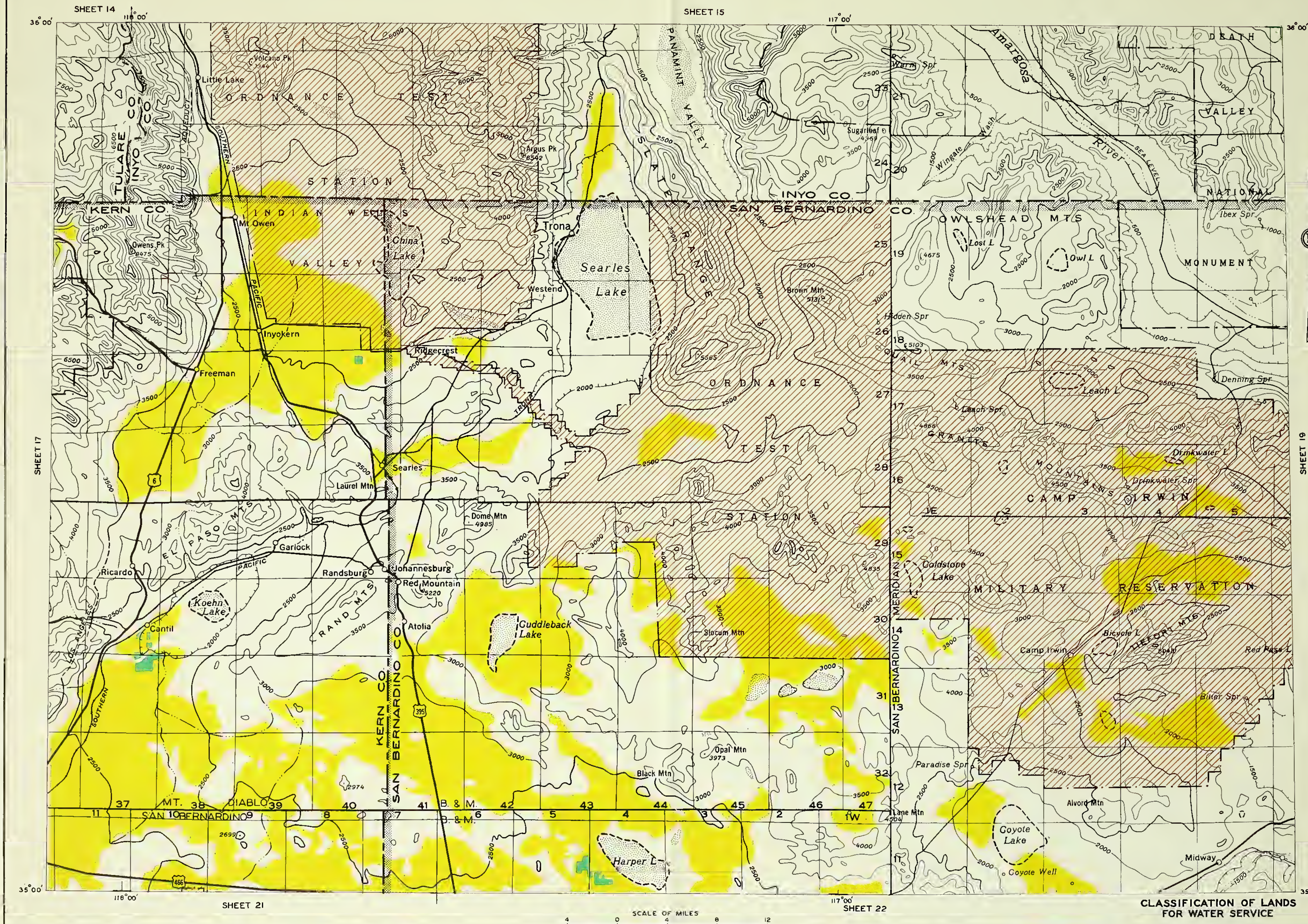


CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 16 OF 26 SHEETS

DIVISION OF WATER RESOURCES

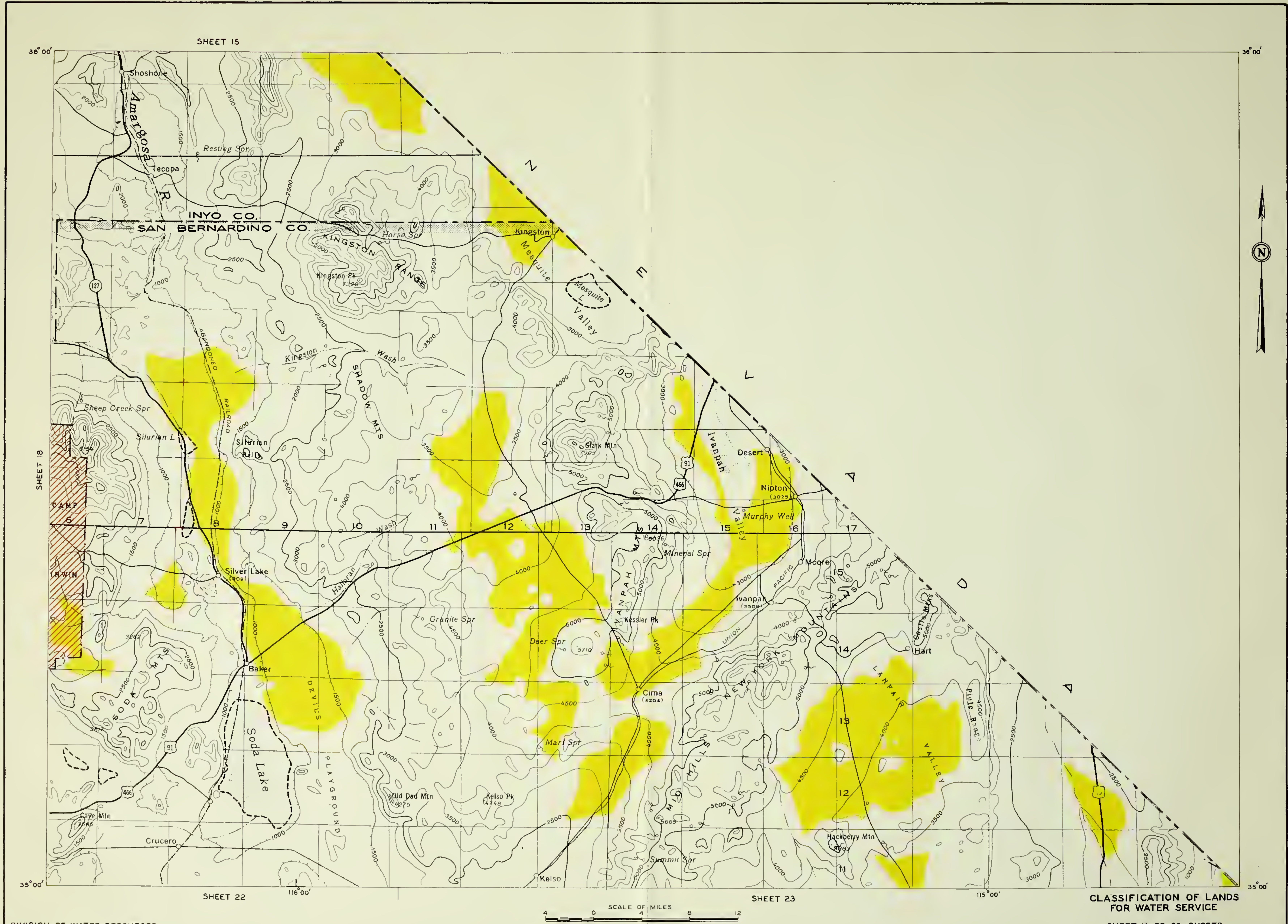

SHEET 14
SHEET 16
SHEET 18
SHEET 20
SHEET 21
Tulare Lake
Angiola
Pixley
Terra Bell
Alpaugh
Earlimart
Ducor
Fountain Sprs
Allensworth
Vestal
KINGS CO.
TULARE CO.
KERN CO.
Jovista
Richgrove
Delano
Pond
Jasmin
McFarland
Lost Hills
Famoso
Wasco
Shafter
Dow
Oildale
Oil City
BAKERSFIELD
Buttonwillow
Rosedale
Edison
Bena
Caliente
McKittrick
Tupman
NAVAL PETROLEUM RESERVE
LUIS OBISPO
SAN
Soda Lake
Fellows
Buena Vista Lake
Ford City
Taft
Maricopa
Lamont
DiGiorgio
Weed Patch
Arvin
Wheeler Ridge
Tehachapi
Monolith
Woodford
Mojave
Kernville
Isabella
Weldon
Onyx
ISABELLA DAM (UNDER CONSTR)
Bodfish
Glenville
Woody
SEQUOIA NAT FOREST
GREENHORN MTS
KERN RIVER
PIUTE MTS
KIAVAH MTS
MT DIABLO
SAN BERNARDINO
B.&M.
LOS ANGELES AQUEDUCT
SCALE OF MILES
CLASSIFICATION OF LANDS FOR WATER SERVICE
SHEET 17 OF 26 SHEETS
DIVISION OF WATER RESOURCES



CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 18 OF 26 SHEETS

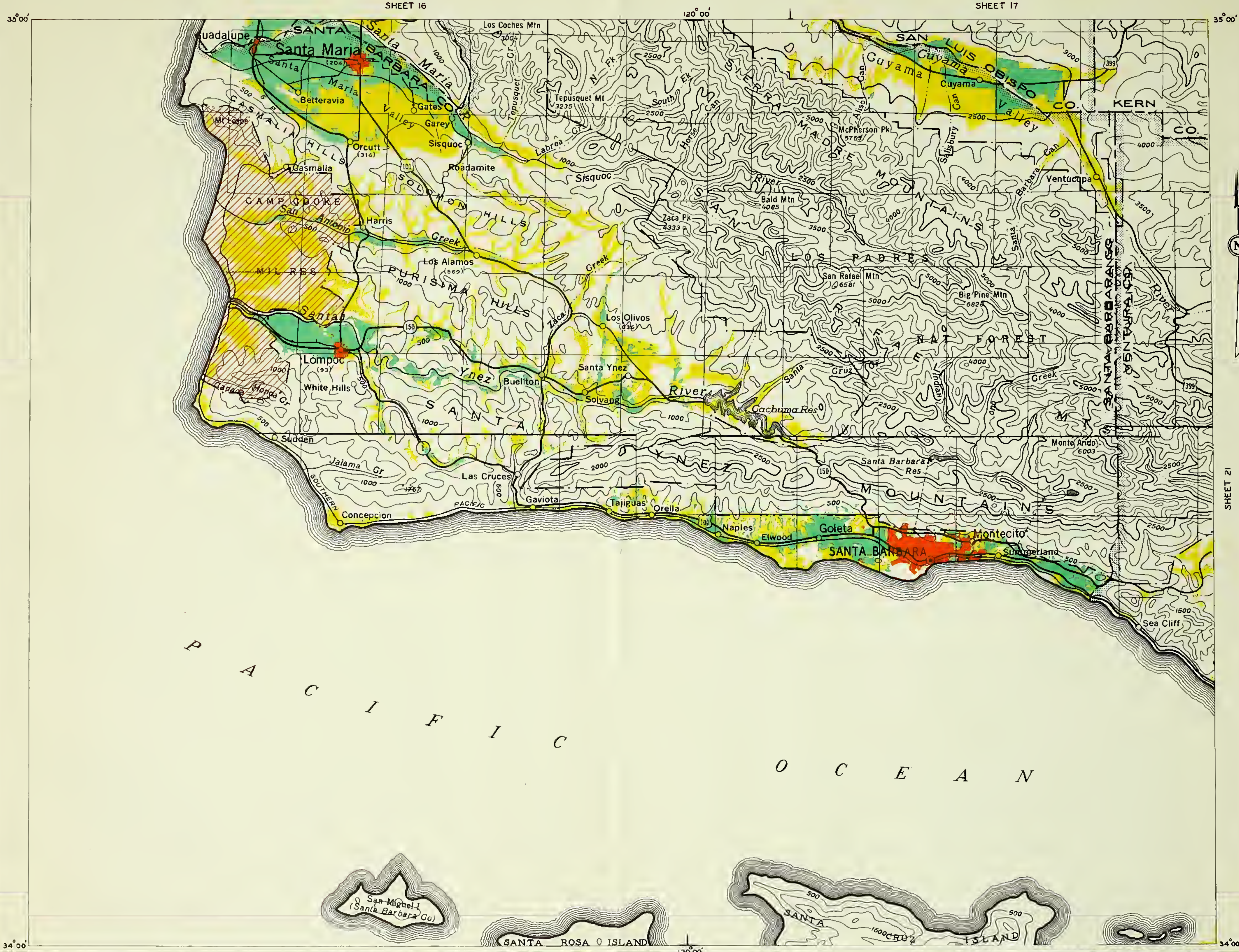
DIVISION OF WATER RESOURCES



DIVISION OF WATER RESOURCES

CLASSIFICATION OF LANDS FOR WATER SERVICE

SHEET 19 OF 26 SHEETS

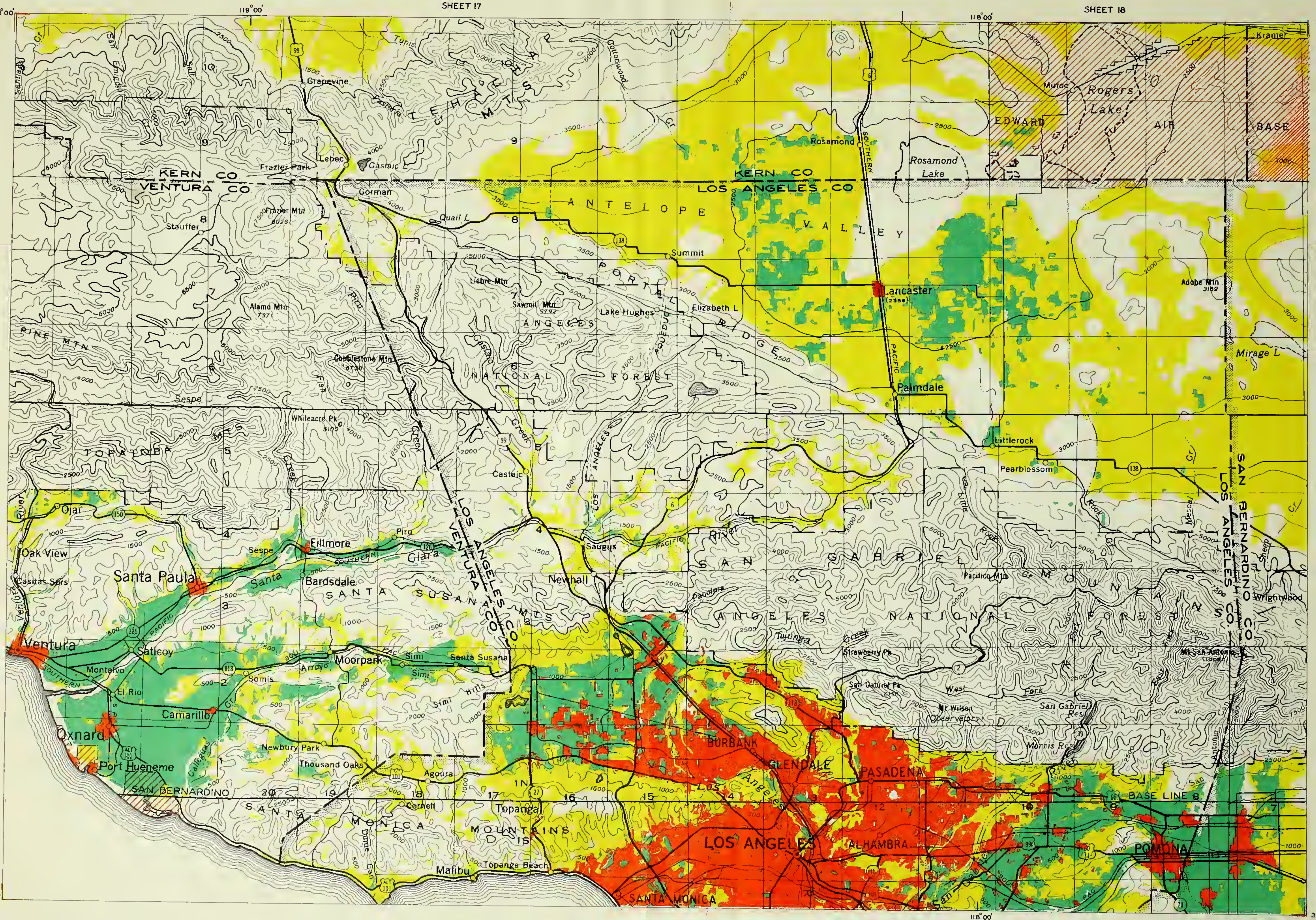


CLASSIFICATION OF LANDS FOR WATER SERVICE

SCALE OF MILES
4 0 4 8 12

SHEET 20 OF 26 SHEETS

DIVISION OF WATER RESOURCES

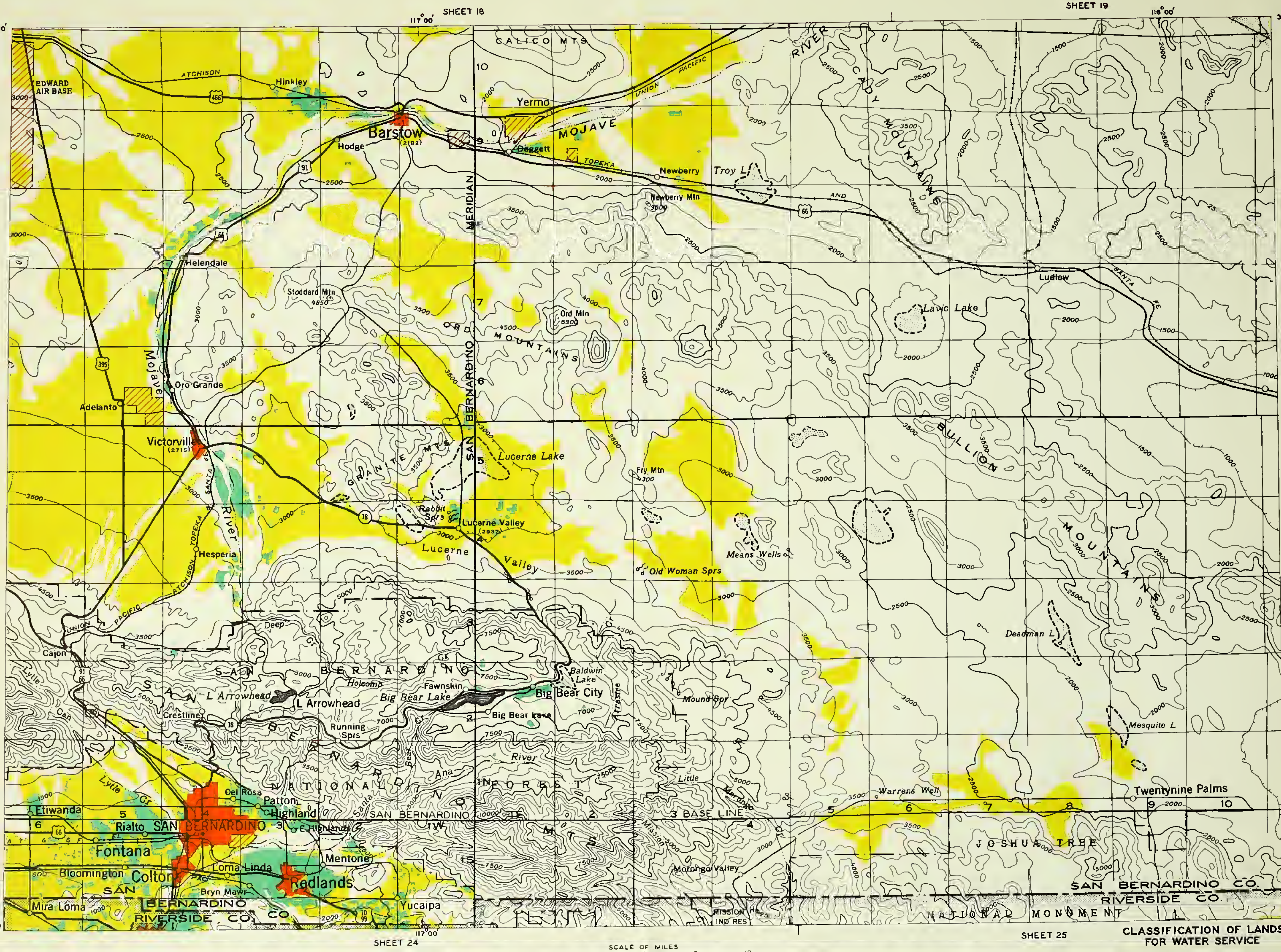


SCALE OF MILES

DIVISION OF WATER RESOURCES

CLASSIFICATION OF LANDS FOR WATER SERVICE

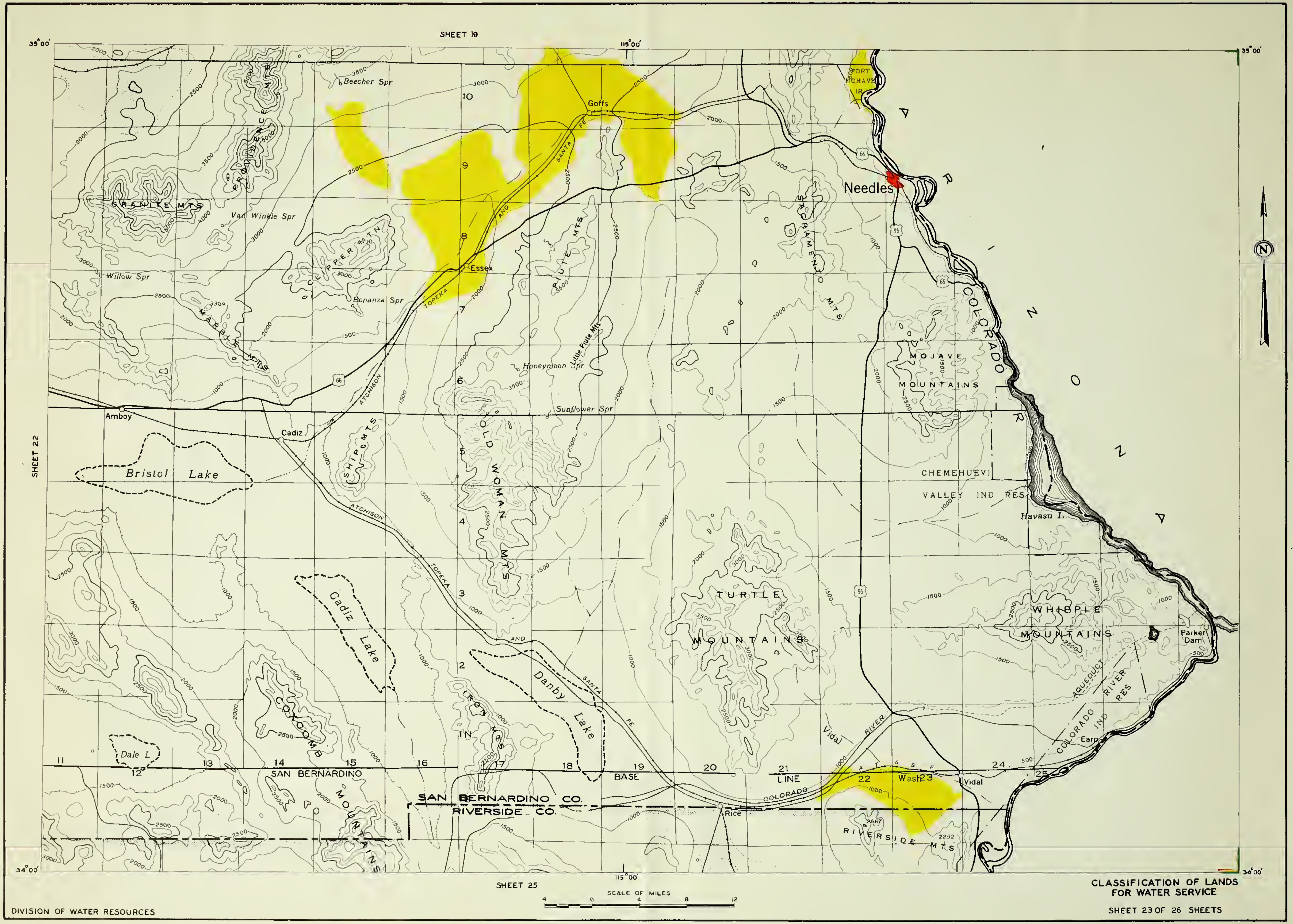
SHEET 21 OF 26 SHEETS



CLASSIFICATION OF LANDS FOR WATER SERVICE

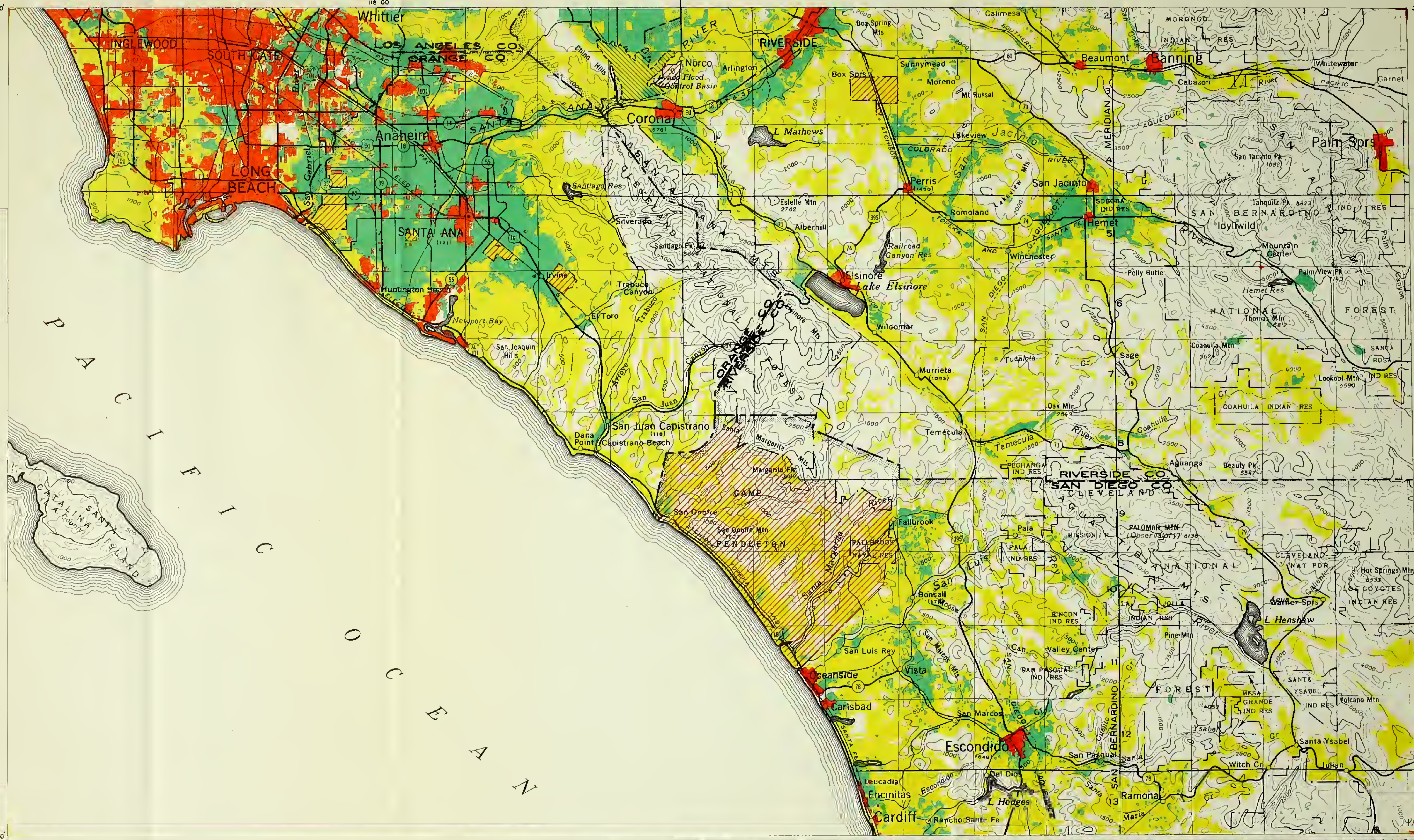
SHEET 22 OF 26 SHEETS

DIVISION OF WATER RESOURCES


SHEET 19
SHEET 22
SHEET 25
35°00′
34°00′
115°00′
Needles
Goffs
Essex
Amboy
Cadiz
Rice
Vidal
Earp
Parker Dam
FORT MOHAVE IR
ARIZONA
COLORADO R
GRANITE MTS
PROVIDENCE MTS
CLIPPER MTN
MARBLE MTS
PIUTE MTS
Little Piute Mts
SACRAMENTO MTS
MOJAVE MOUNTAINS
CHEMEHUEVI VALLEY IND RES
Havasu L.
SHIP MTS
OLD WOMAN MTS
TURTLE MOUNTAINS
WHIPPLE MOUNTAINS
COLORADO RIVER IND RES
COXCOMB MTS
IRON MTS
SAN BERNARDINO MOUNTAINS
RIVERSIDE MTS
Bristol Lake
Cadiz Lake
Danby Lake
Dale L
Beecher Spr
Van Winkle Spr
Willow Spr
Bonanza Spr
Honeymoon Spr
Sunflower Spr
Vidal Wash
ATCHISON TOPEKA AND SANTA FE
RIVER AQUEDUCT
SAN BERNARDINO BASE LINE
SAN BERNARDINO CO.
RIVERSIDE CO.
SCALE OF MILES
4 0 4 8 12
DIVISION OF WATER RESOURCES
CLASSIFICATION OF LANDS FOR WATER SERVICE
SHEET 23 OF 26 SHEETS

SHEET 21

SHEET 22



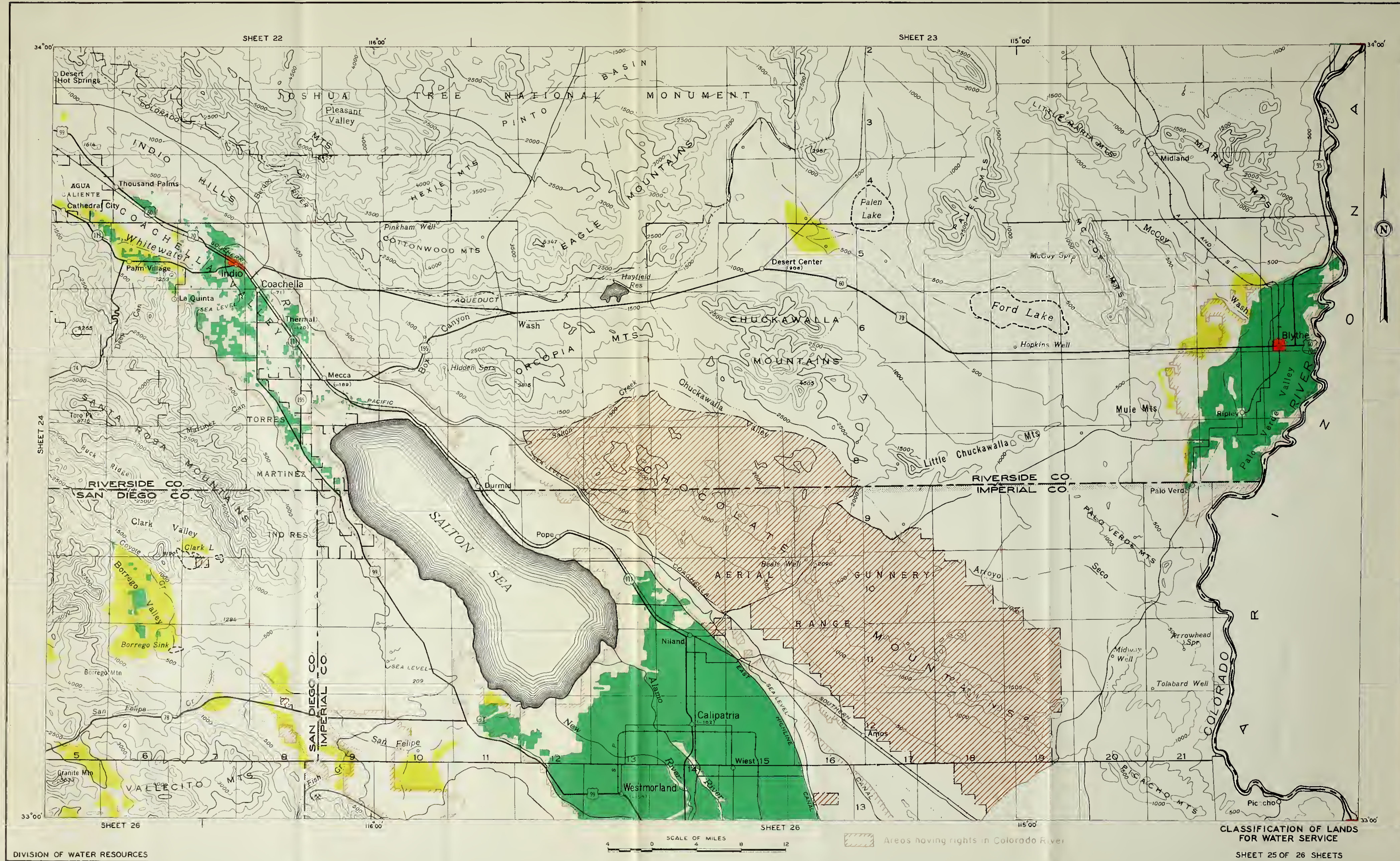
CLASSIFICATION OF LANDS FOR WATER SERVICE

SCALE OF MILES

4 0 4 8 12

DIVISION OF WATER RESOURCES

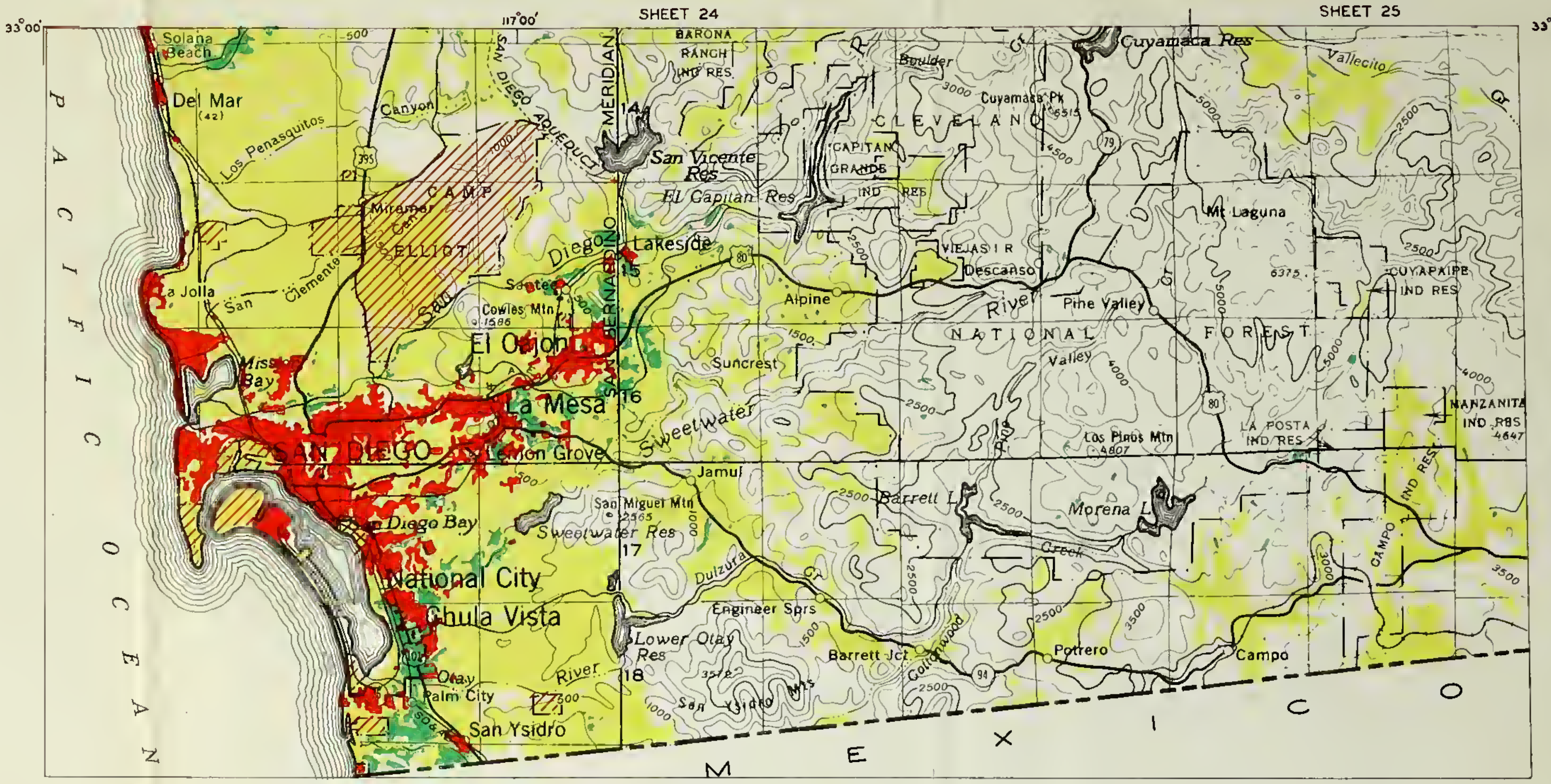
SHEET 24 OF 26 SHEETS



CLASSIFICATION OF LANDS FOR WATER SERVICE

DIVISION OF WATER RESOURCES

SHEET 25 OF 26 SHEETS



SCALE OF MILES

4 0 4 8 12

CLASSIFICATION OF LANDS FOR WATER SERVICE

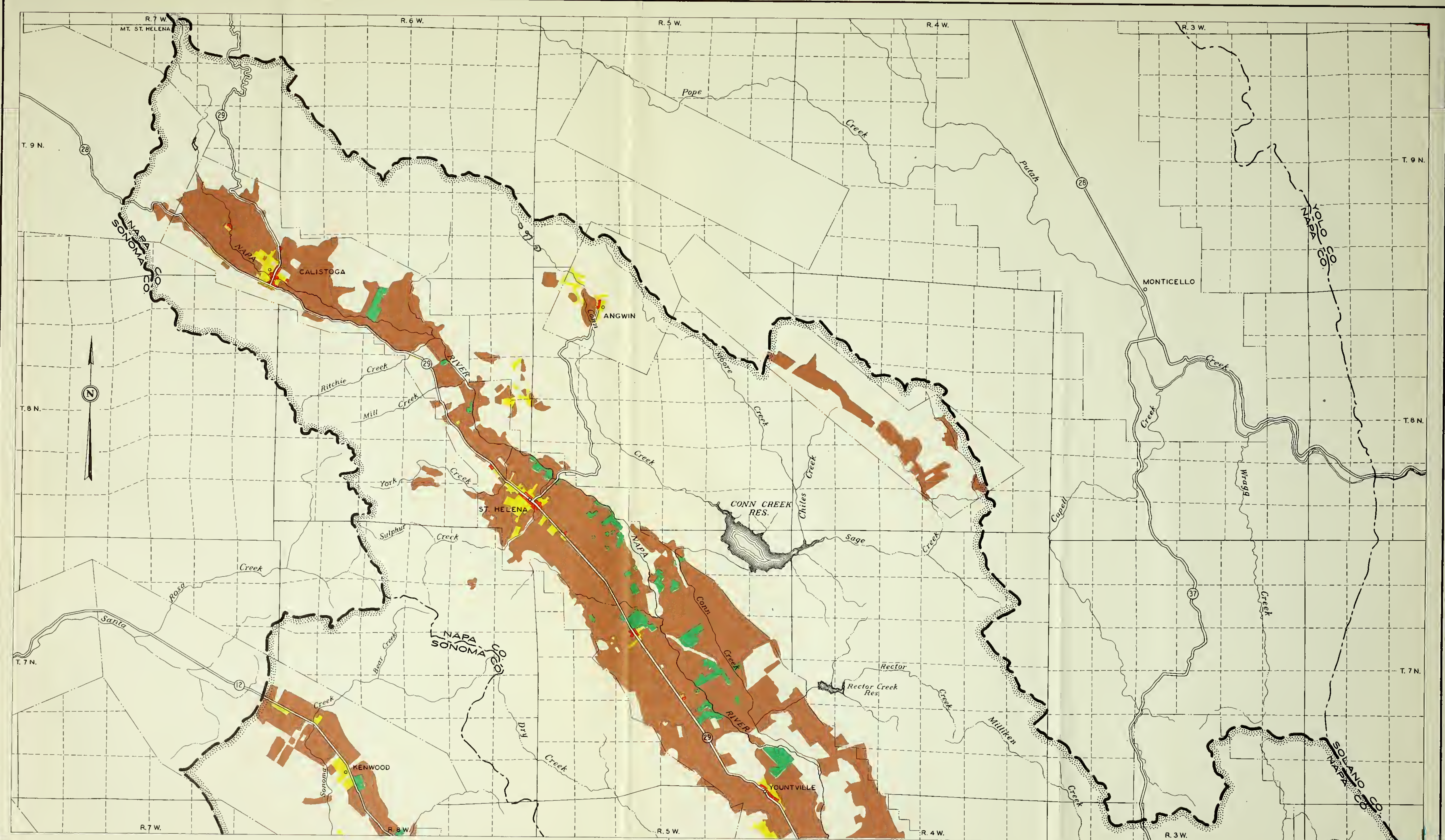
SHEET 26 OF 26 SHEETS

DIVISION OF WATER RESOURCES

STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

PRESENT LAND USE IN SAN FRANCISCO BAY AREA 1949

INDEX TO SHEETS



SHEET 2 | SHEET 3

SCALE OF MILES

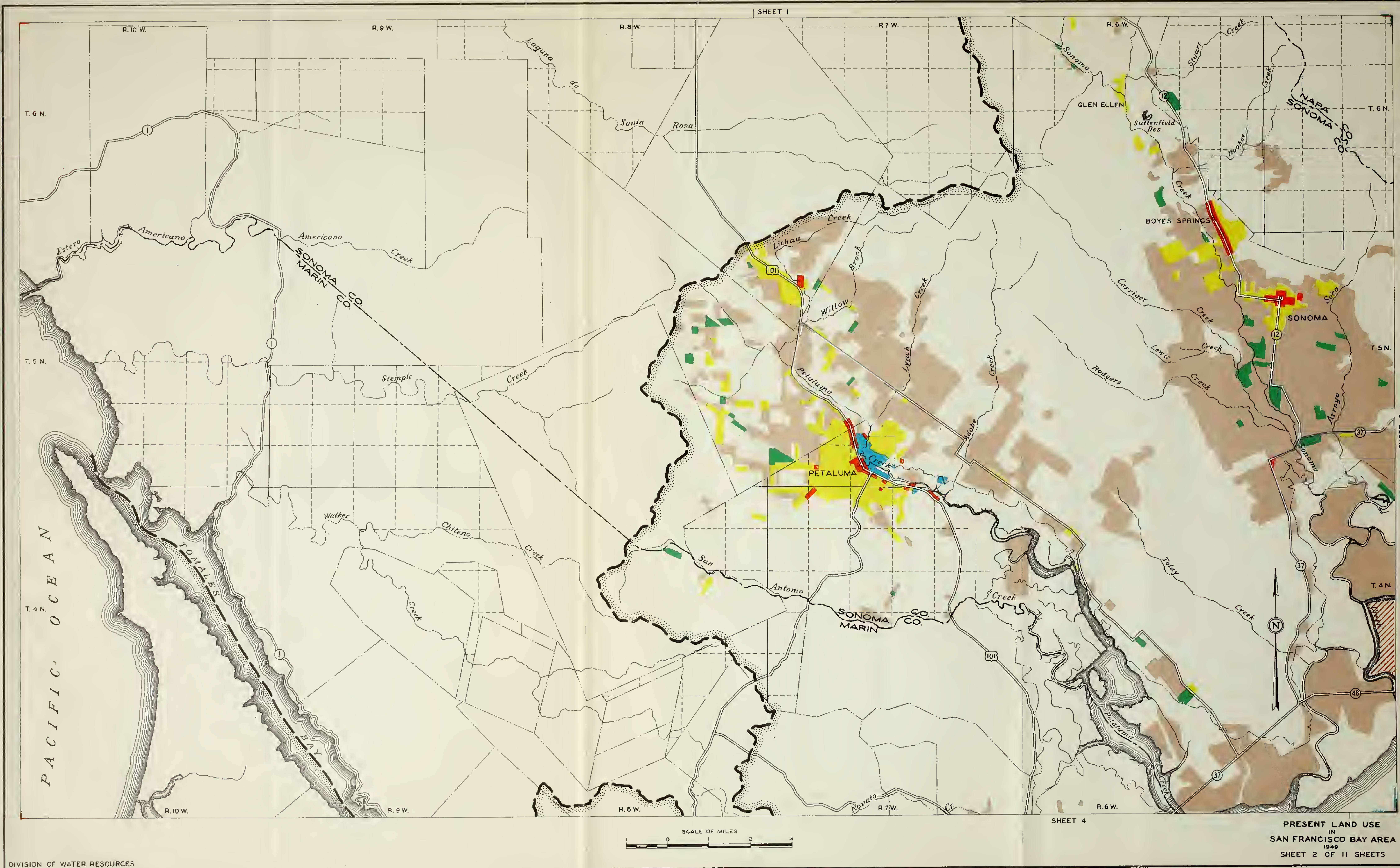
1 0 1 2 3

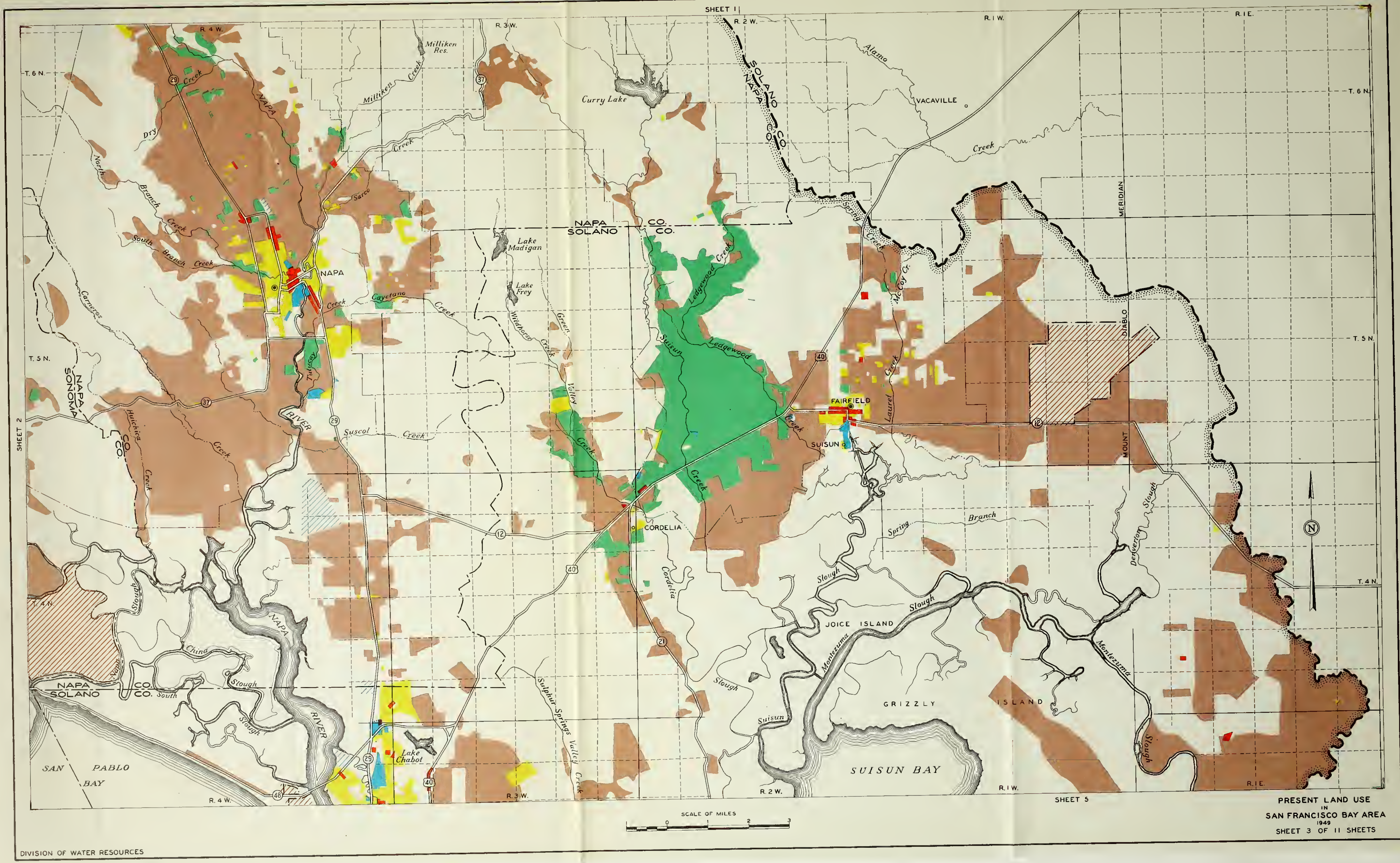
DIVISION OF WATER RESOURCES

PRESENT LAND USE IN SAN FRANCISCO BAY AREA

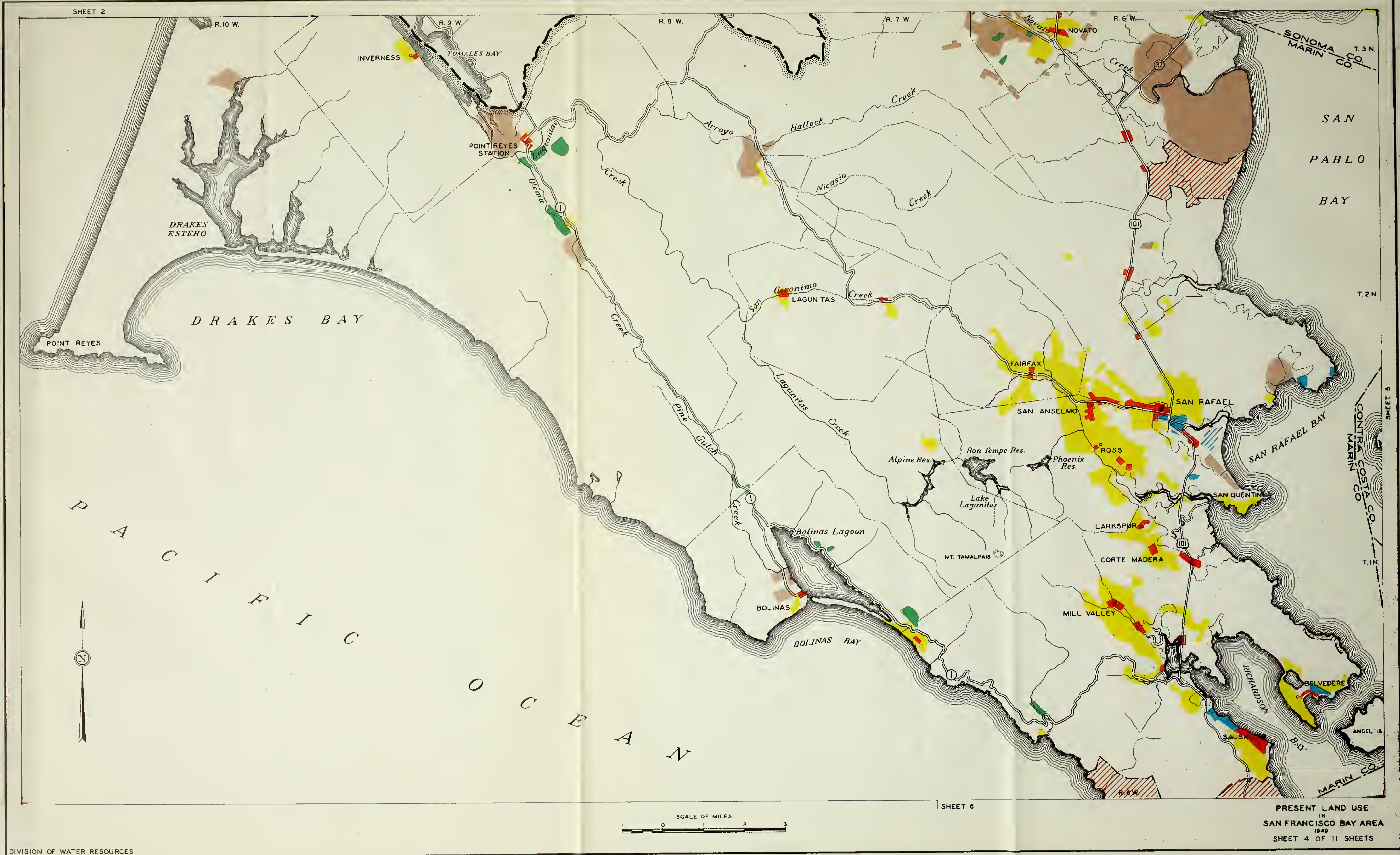
1949

SHEET 1 OF 11 SHEETS


SHEET 1
R.10 W.
R.9 W.
R.8 W.
R.7 W.
R.6 W.
T. 6 N.
T. 5 N.
T. 4 N.
PACIFIC OCEAN
TOMALES BAY
SONOMA CO.
MARIN CO.
GLEN ELLEN
BOYES SPRINGS
SONOMA
PETALUMA
NAPA CO.
SONOMA CO.
Suttenfield Res.
Laguna de Santa Rosa
Estero Americano
Americano Creek
Stemple Creek
Walker Creek
Chileno Creek
San Antonio Creek
Lichau Creek
Willow Brook
Lynch Creek
Petaluma Creek
Adobe Creek
Carriger Creek
Rodgers Creek
Lewis Creek
Arroyo Seco
Tolay Creek
Stuart Creek
Hooker Creek
Sonoma Creek
Novato Cr.
SHEET 3
SHEET 4
SCALE OF MILES
1 0 1 2 3
PRESENT LAND USE
IN
SAN FRANCISCO BAY AREA
1949
SHEET 2 OF 11 SHEETS
DIVISION OF WATER RESOURCES

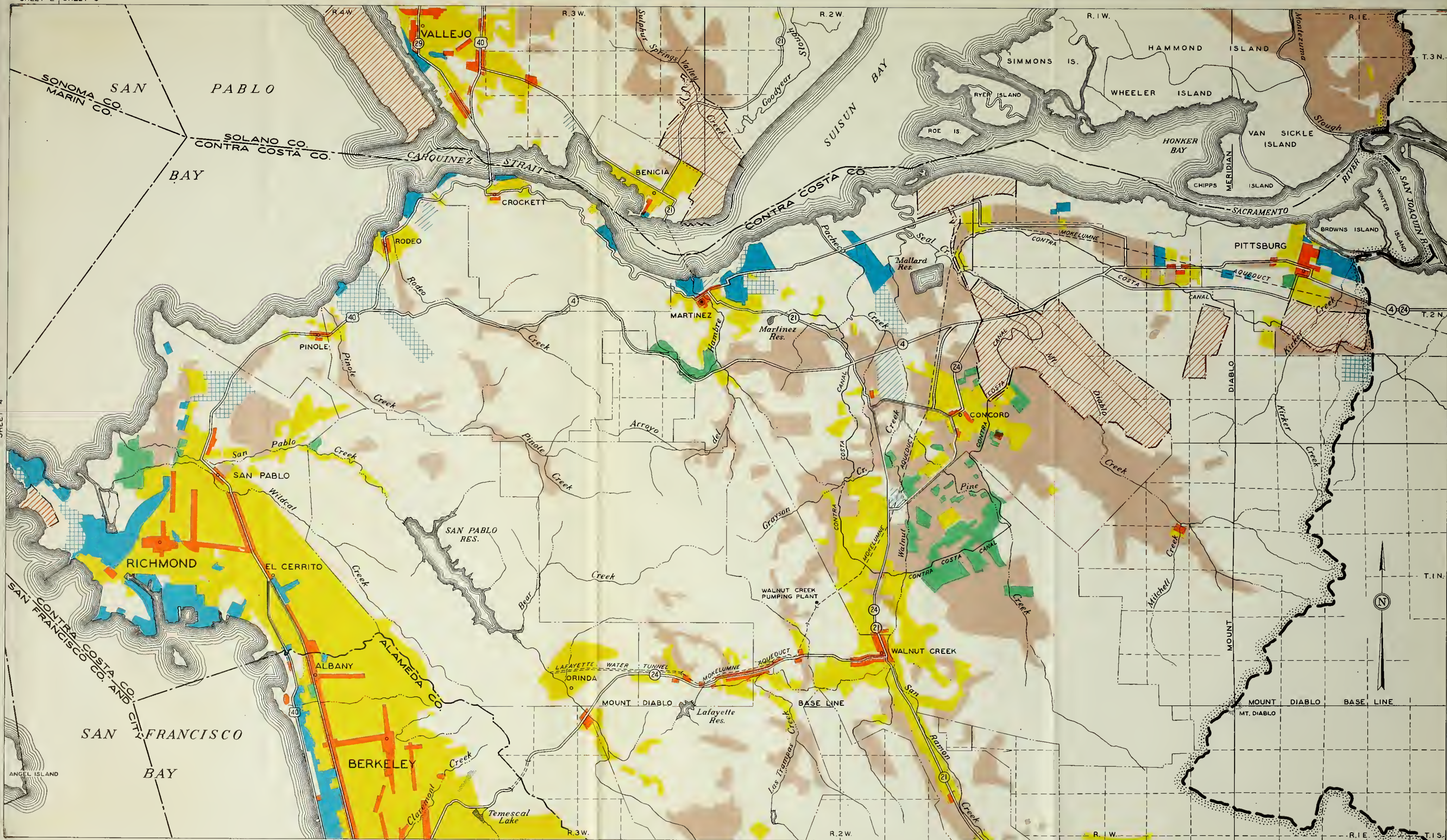


SHEET 1
R. 4 W.
R. 3 W.
R. 2 W.
R. 1 W.
R. 1 E.
T. 6 N.
T. 5 N.
T. 4 N.
Milliken Res.
Milliken Creek
Curry Lake
Alamo
VACAVILLE
Creek
NAPA
Dry
North Branch Creek
South Branch Creek
Sarco
NAPA SOLANO CO. CO.
SOLANO CO. NAPA CO.
Lake Madigan
Lake Frey
Spring Creek
McCoy Cr.
MERIDIAN
DIABLO
MOUNT
Carneros
Cayetano Creek
Ledgewood Creek
Suisun
Wildhorse Creek
Green Valley Creek
Tulucay
NAPA SONOMA CO. CO.
SHEET 2
Huichica Creek
RIVER
Suscol Creek
FAIRFIELD
Laurel Creek
SUISUN
CORDELIA
Cordelia
Spring Branch
Denverton Slough
Slough
China Slough
Napa
JOICE ISLAND
Montezuma Slough
GRIZZLY ISLAND
Suisun
SUISUN BAY
Sulphur Springs Valley Creek
NAPA SOLANO CO. CO.
South Slough
Lake Chabot
SAN PABLO BAY
SHEET 5
SCALE OF MILES
0 1 2 3
PRESENT LAND USE IN SAN FRANCISCO BAY AREA 1949
SHEET 3 OF 11 SHEETS
DIVISION OF WATER RESOURCES



PRESENT LAND USE IN SAN FRANCISCO BAY AREA 1949

SHEET 4 OF 11 SHEETS

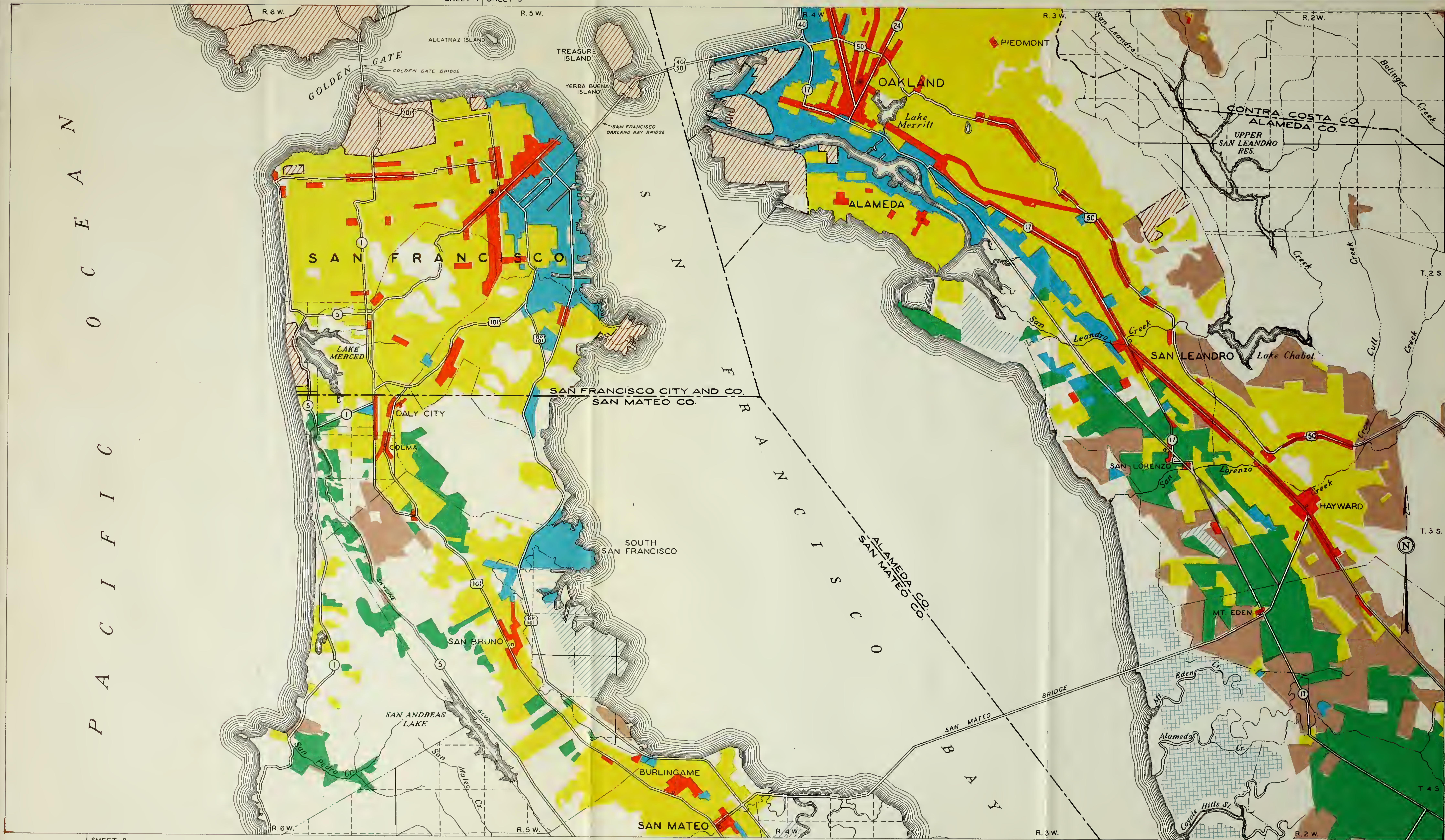


SCALE OF MILES

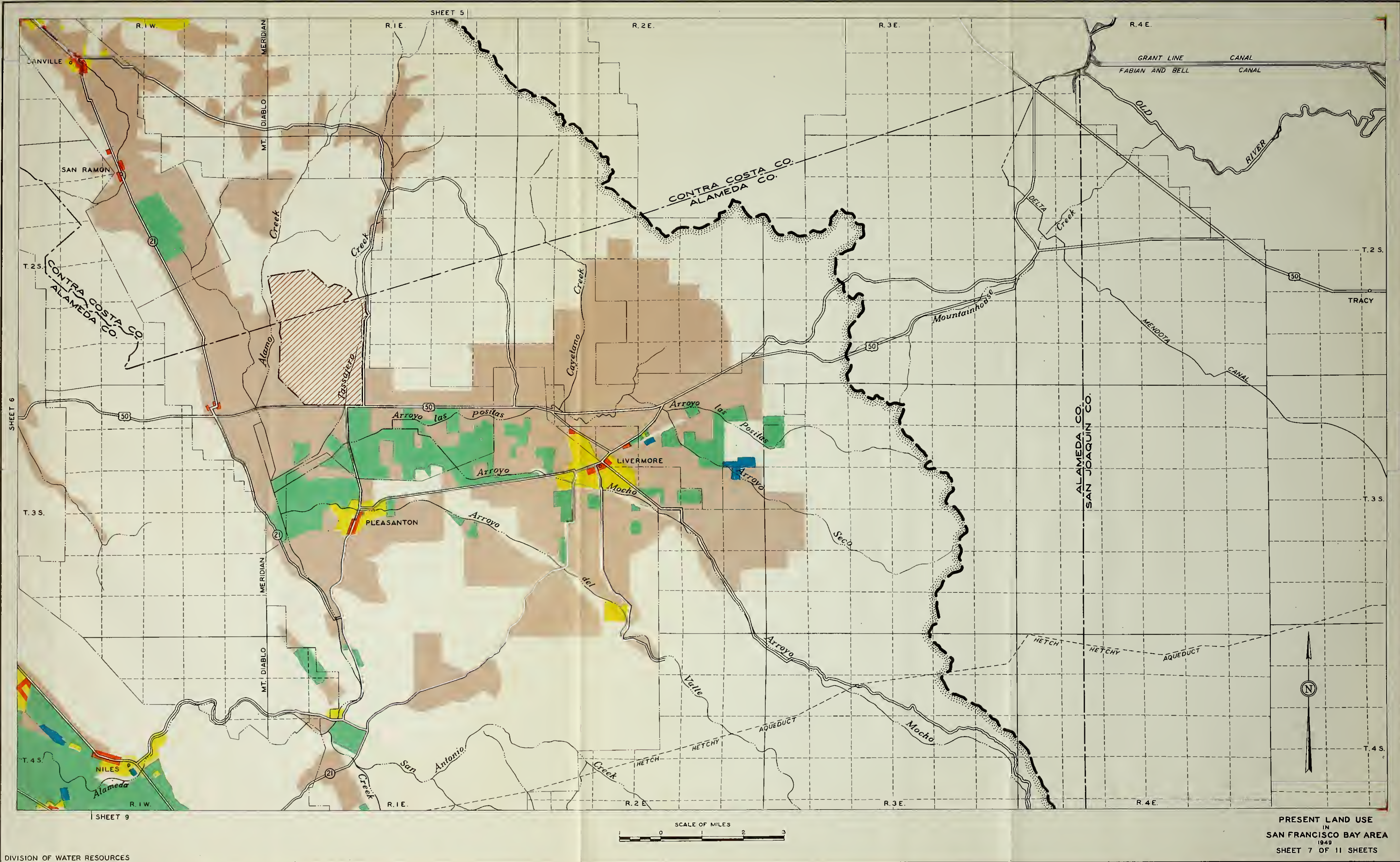
0 1 2 3

PRESENT LAND USE
IN
SAN FRANCISCO BAY AREA
1949
SHEET 5 OF 11 SHEETS

DIVISION OF WATER RESOURCES



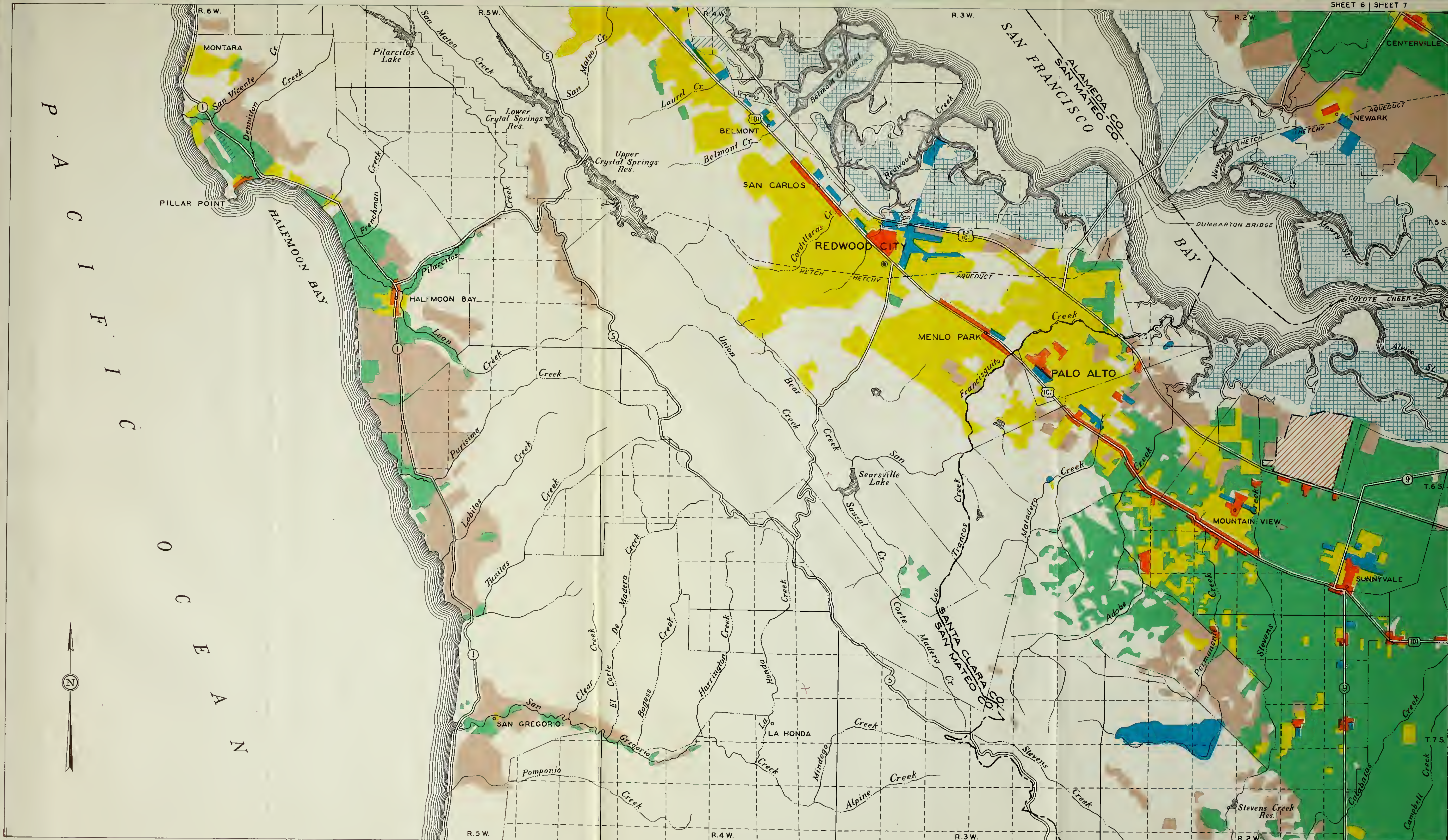
PRESENT LAND USE
IN
SAN FRANCISCO BAY AREA
1949
SHEET 6 OF 11 SHEETS



SCALE OF MILES

DIVISION OF WATER RESOURCES

PRESENT LAND USE
IN
SAN FRANCISCO BAY AREA
1949
SHEET 7 OF 11 SHEETS

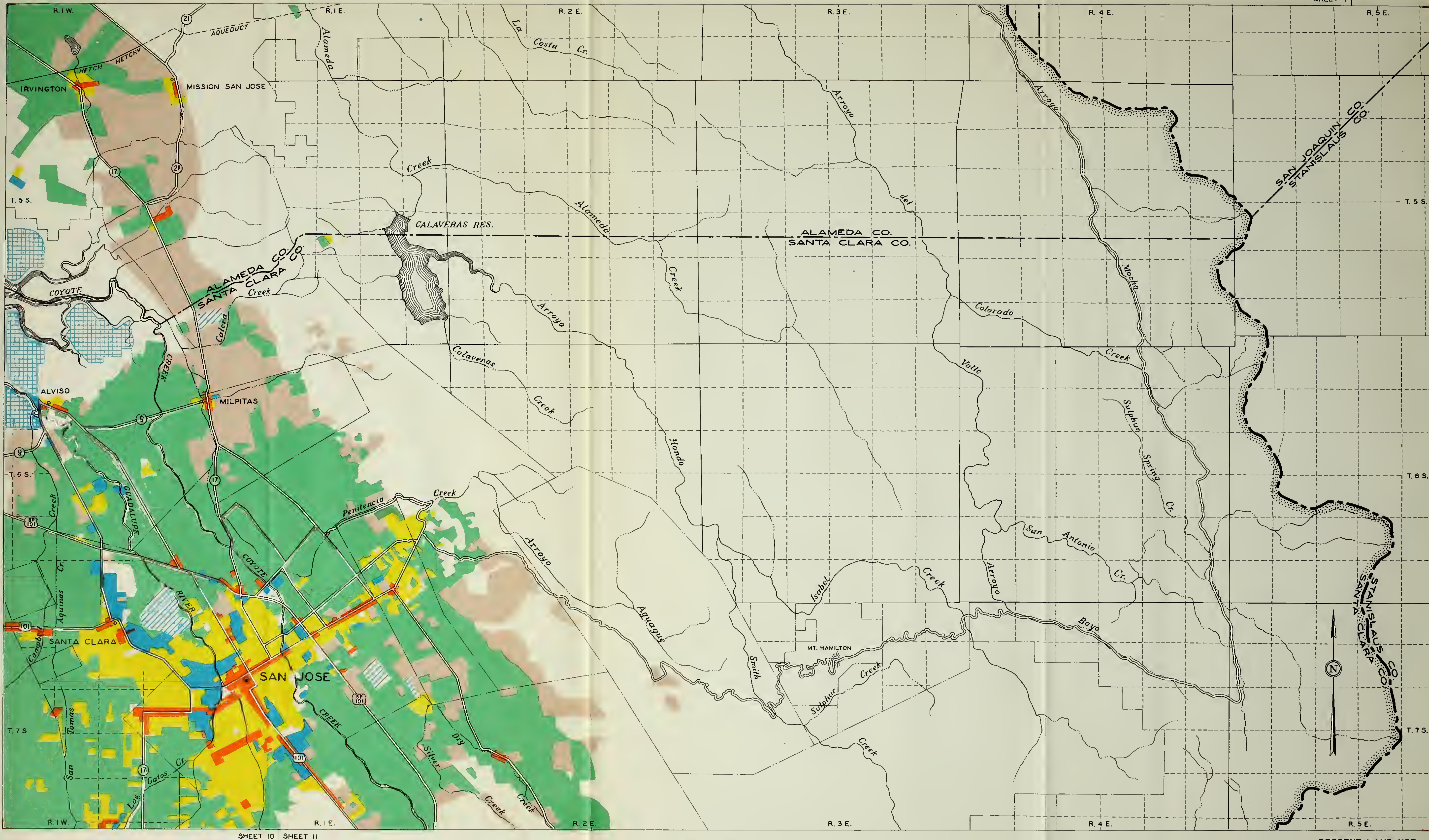


SHEET 10

SCALE OF MILES

DIVISION OF WATER RESOURCES

PRESENT LAND USE
IN
SAN FRANCISCO BAY AREA
1949
SHEET 8 OF 11 SHEETS



SCALE OF MILES

PRESENT LAND USE
IN
SAN FRANCISCO BAY AREA
1949
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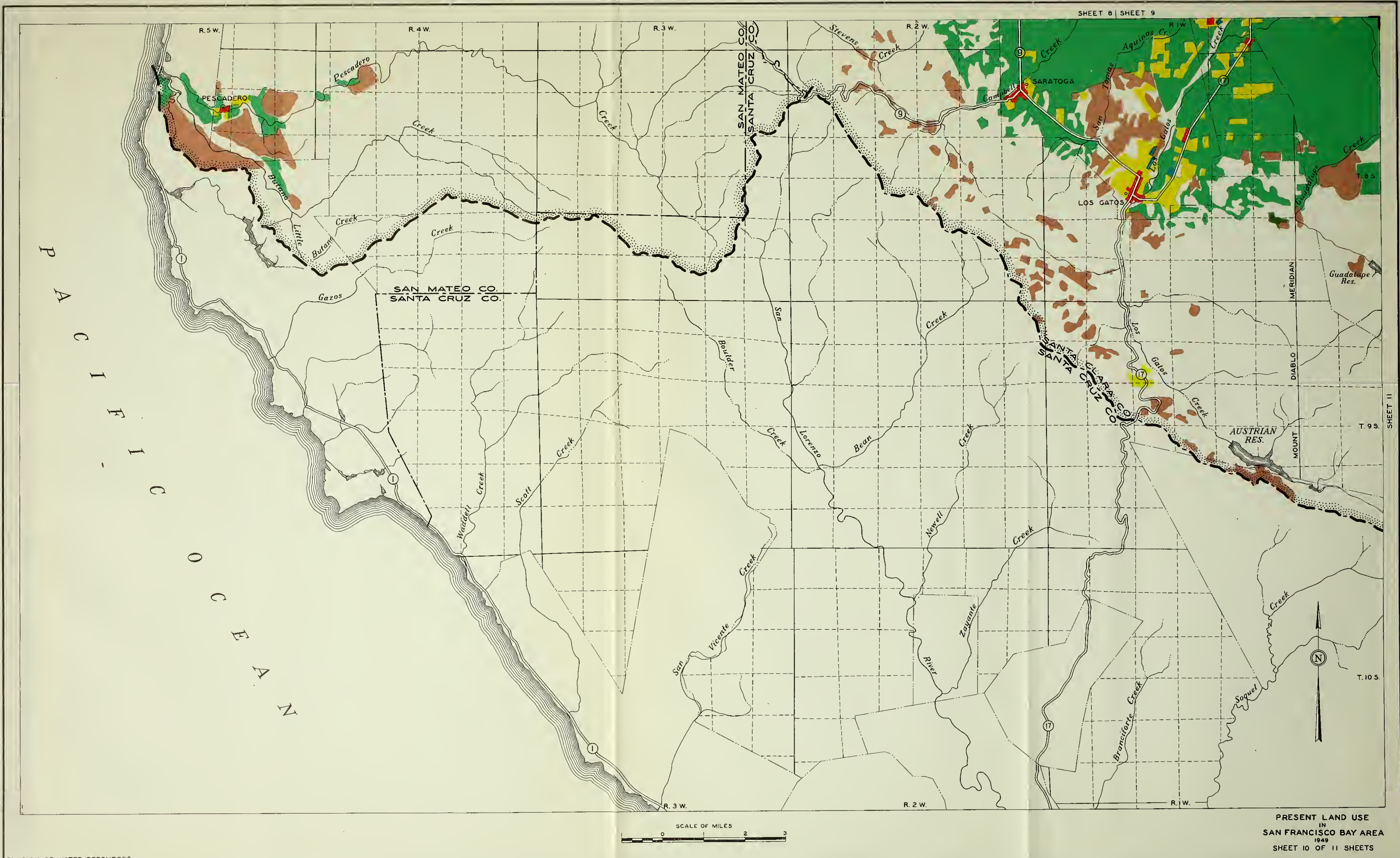
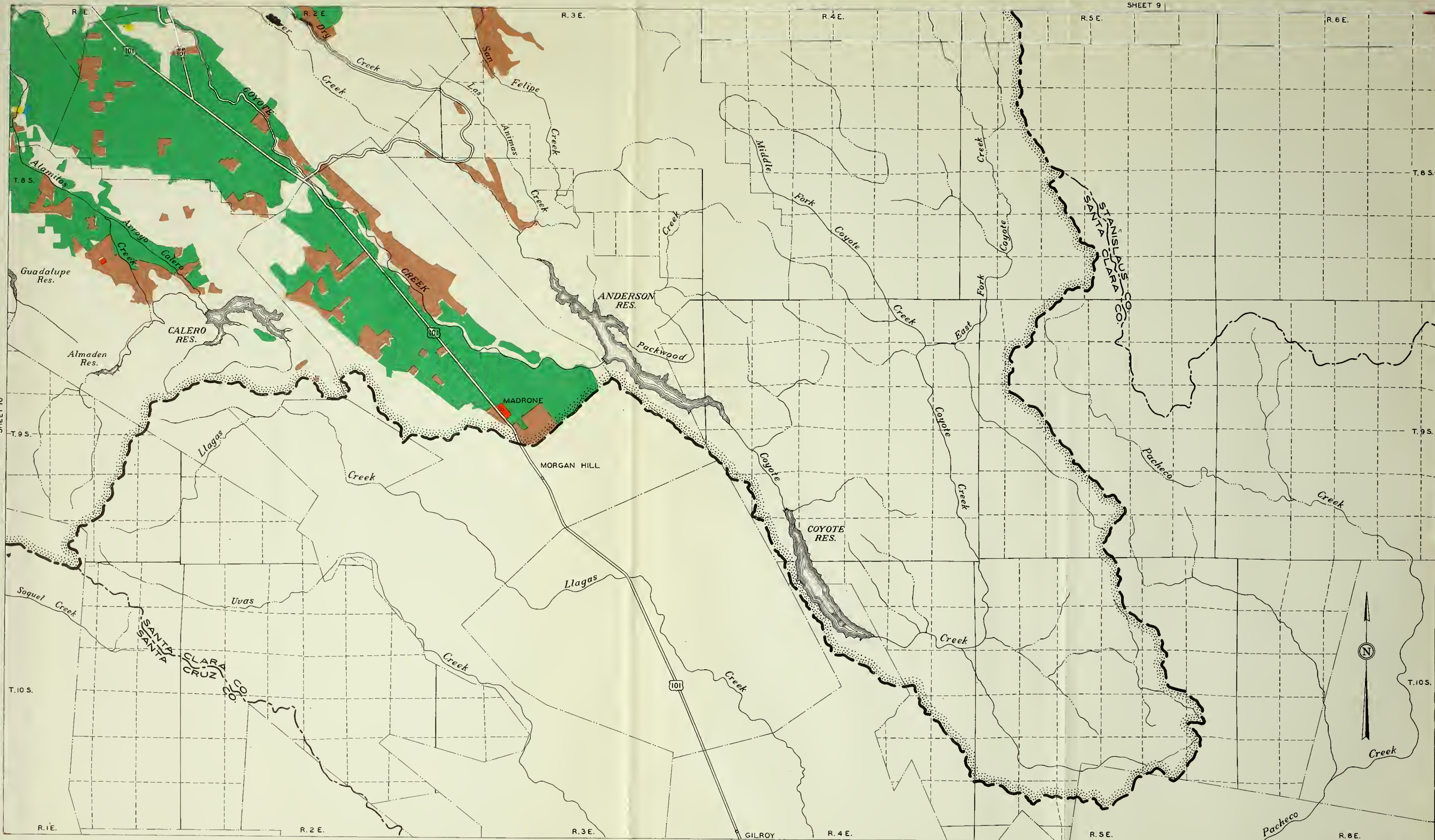
DIVISION OF WATER RESOURCES



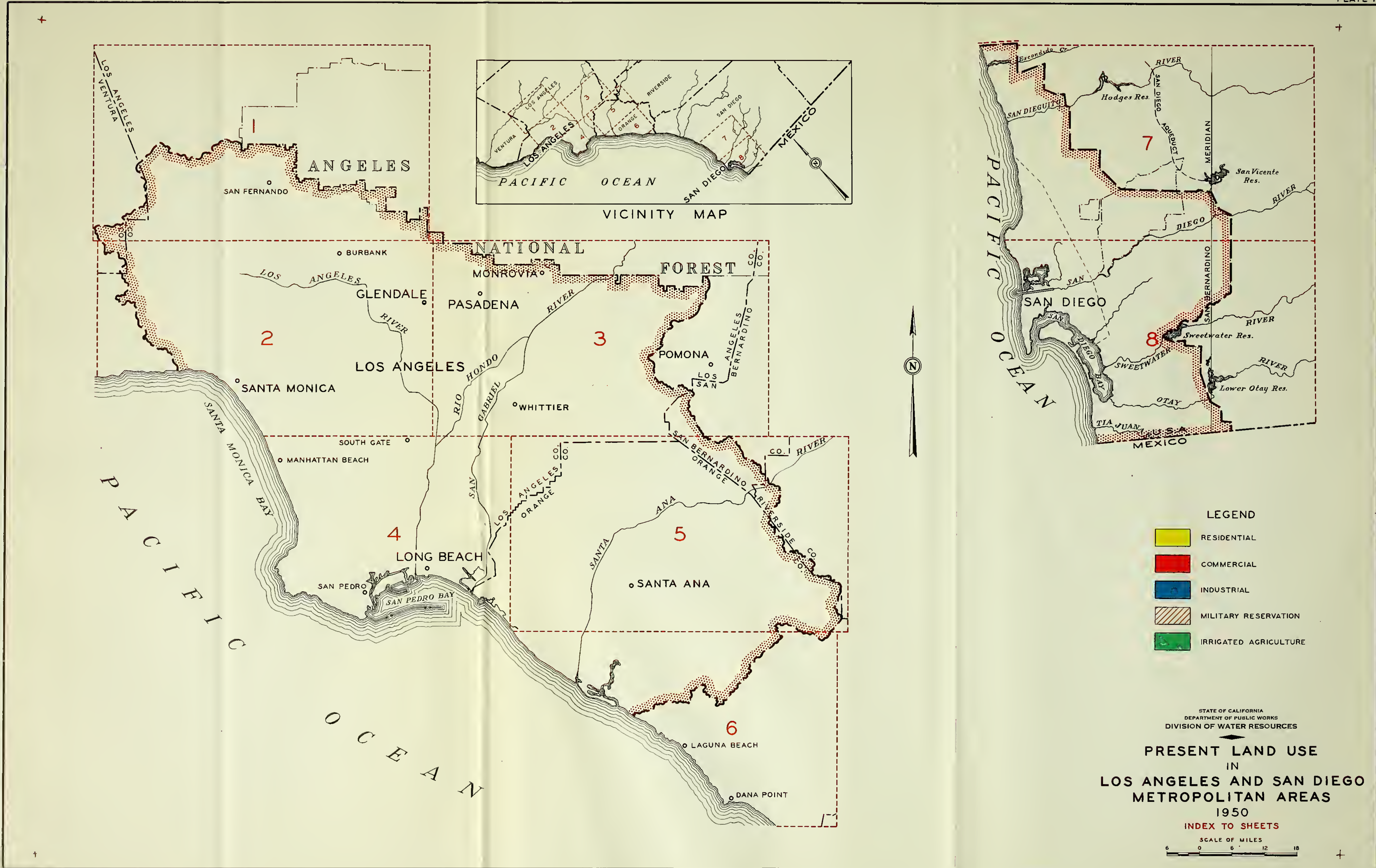
PRESENT LAND USE
IN
SAN FRANCISCO BAY AREA
1949
SHEET 10 OF 11 SHEETS

DIVISION OF WATER RESOURCES



DIVISION OF WATER RESOURCES

PRESENT LAND USE IN SAN FRANCISCO BAY AREA
1949
SHEET 11 OF 11 SHEETS

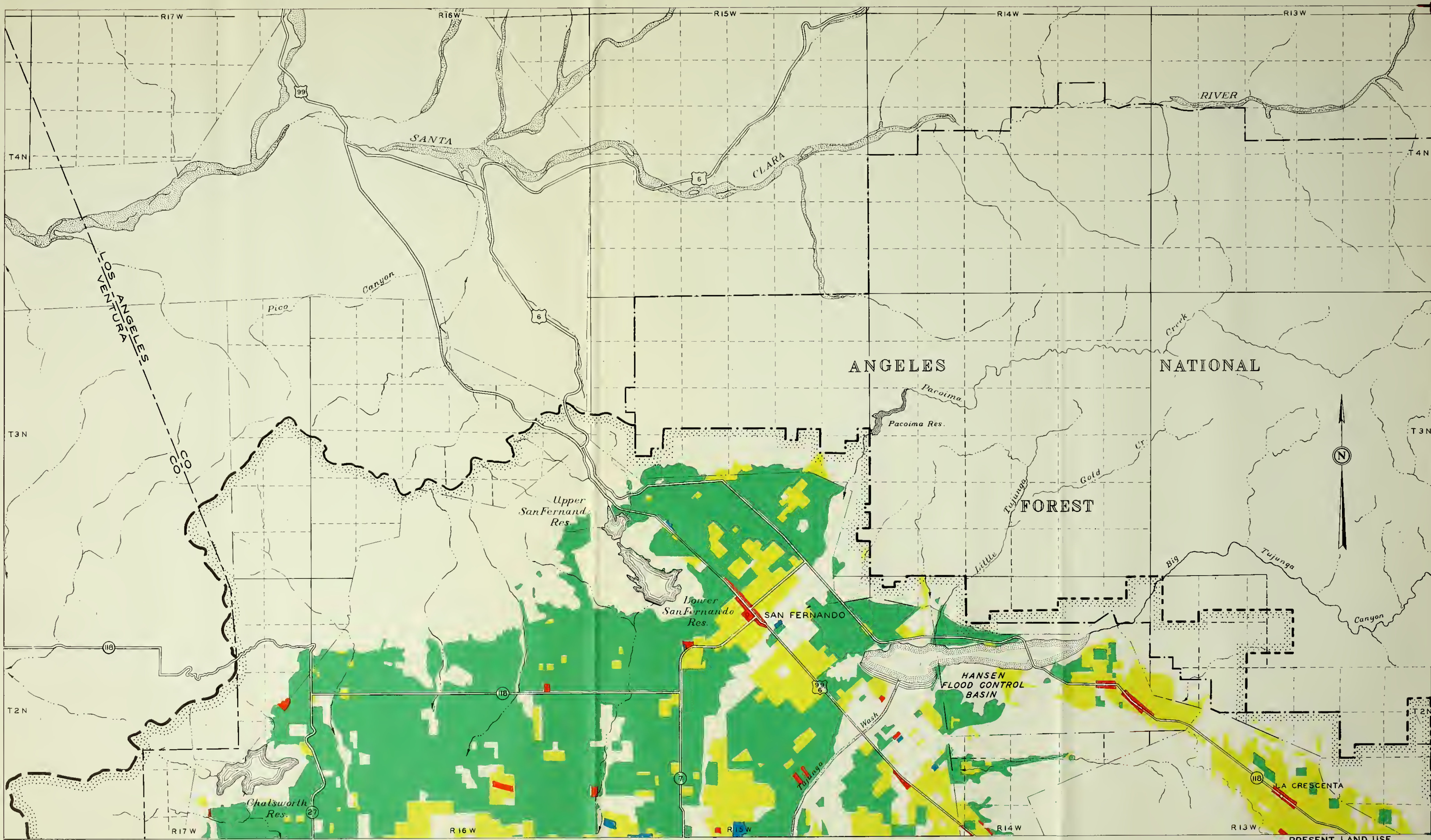


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

PRESENT LAND USE IN LOS ANGELES AND SAN DIEGO METROPOLITAN AREAS 1950

INDEX TO SHEETS

SCALE OF MILES
6 0 6 12 18

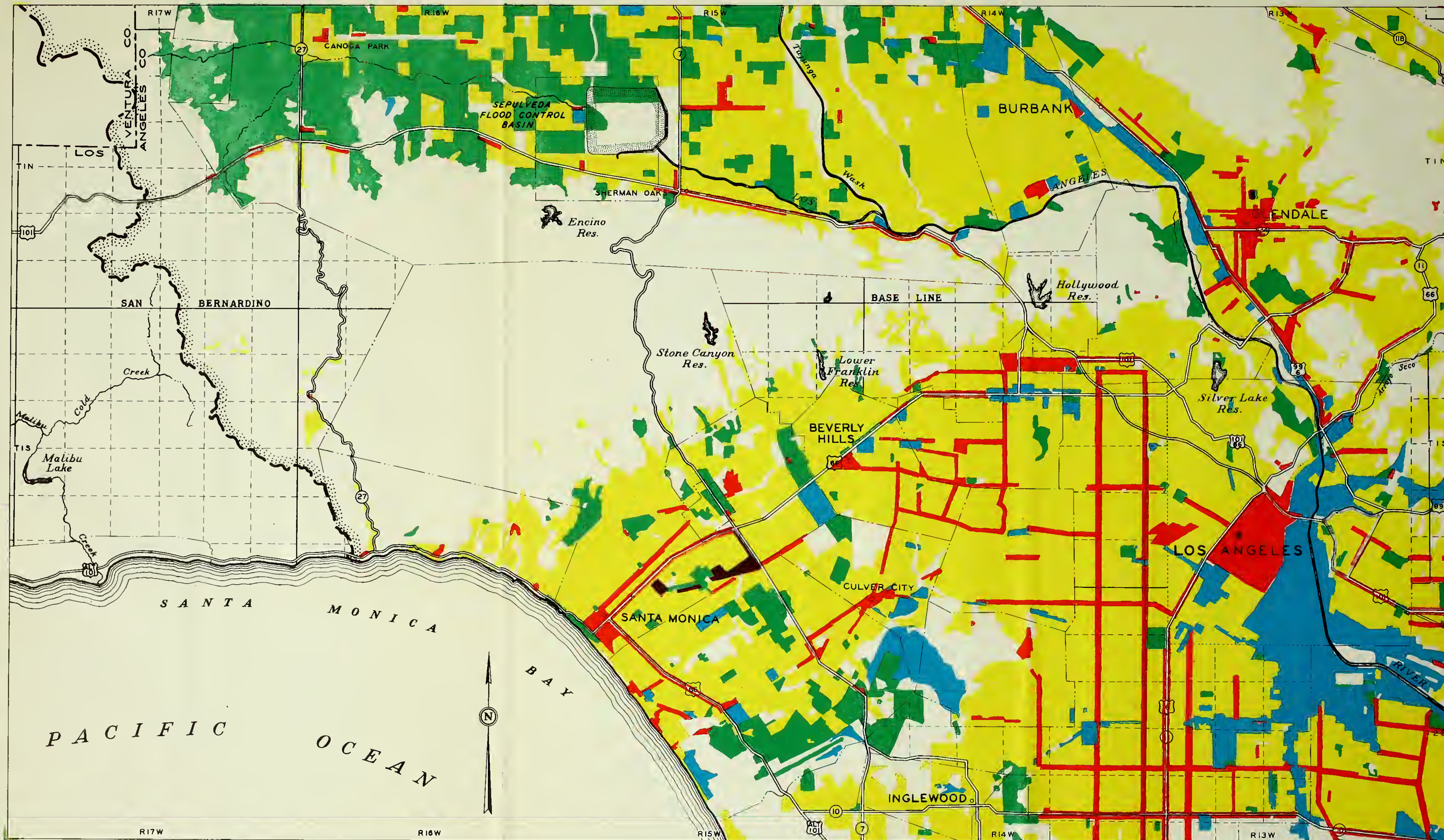


SHEET 2

PRESENT LAND USE
IN
LOS ANGELES METROPOLITAN AREA
1950
SHEET 1 OF 8 SHEETS

DIVISION OF WATER RESOURCES

SHEET 1



SHEET 3

SHEET 4

SCALE OF MILES

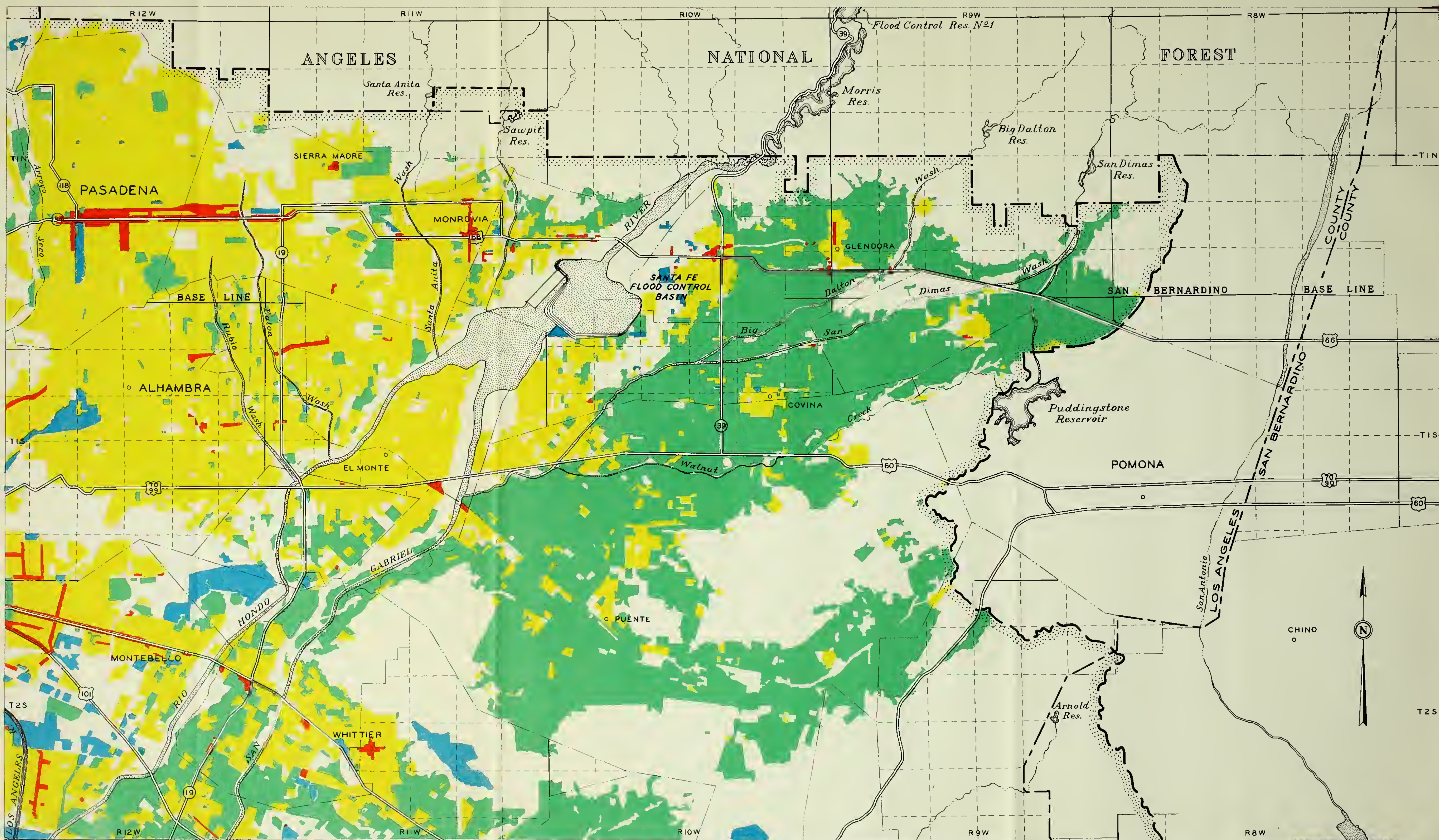
1 0 1 2 3

DIVISION OF WATER RESOURCES

PRESENT LAND USE IN LOS ANGELES METROPOLITAN AREA

1950

SHEET 2 OF 8 SHEETS



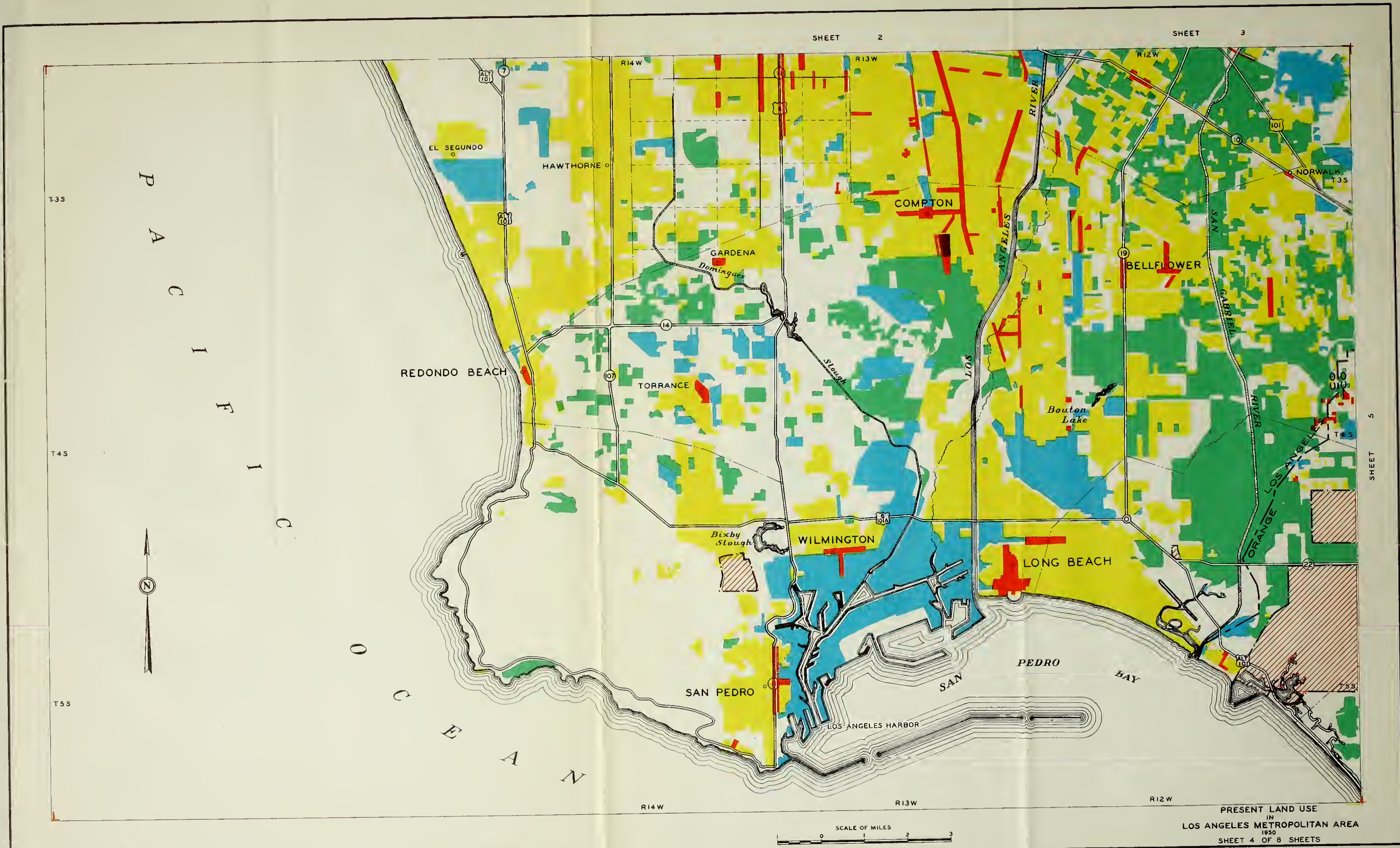
SHEET 4 SHEET 5

SCALE OF MILES 1 0 1 2 3

PRESENT LAND USE IN LOS ANGELES METROPOLITAN AREA 1950

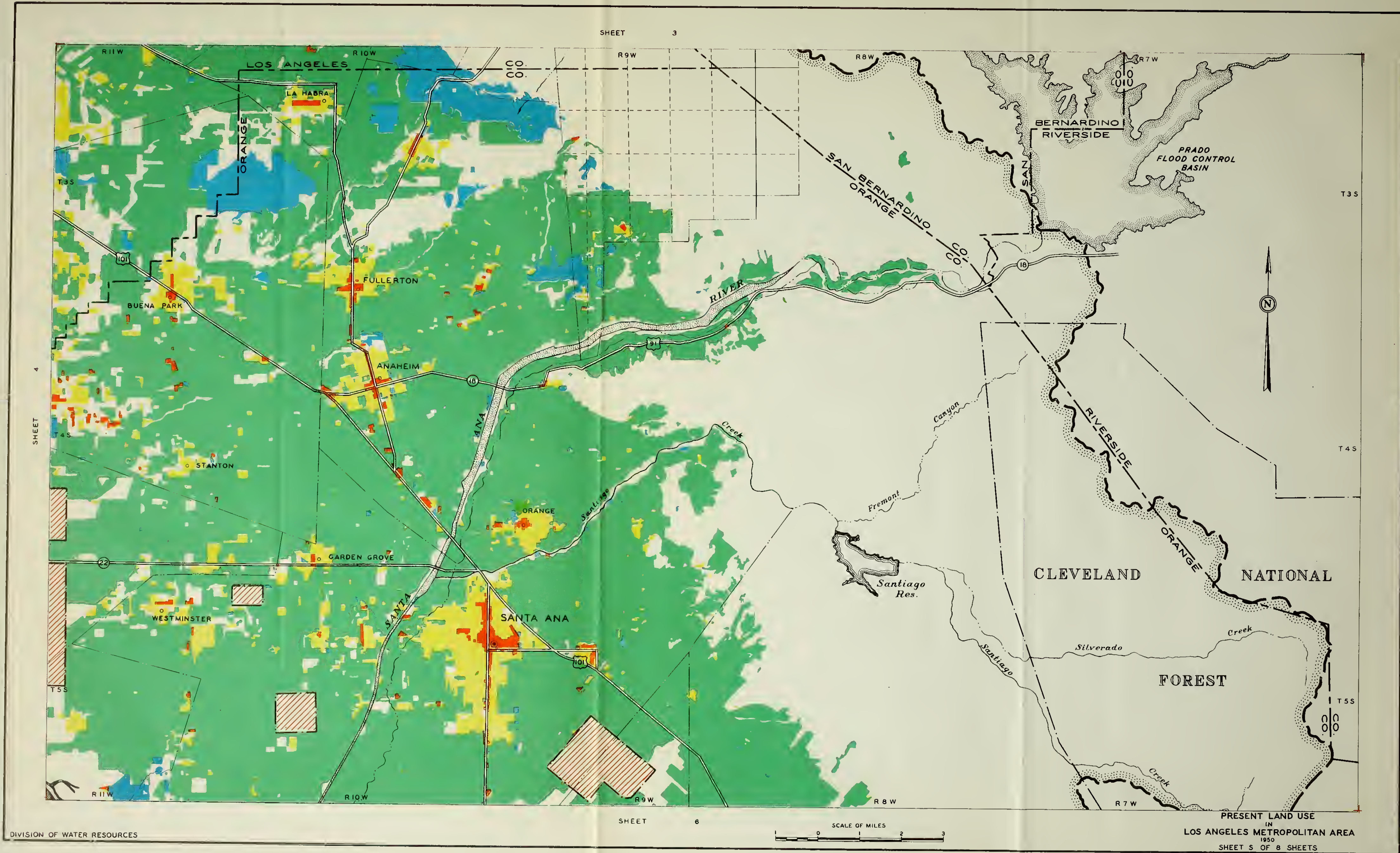
SHEET 3 OF 8 SHEETS

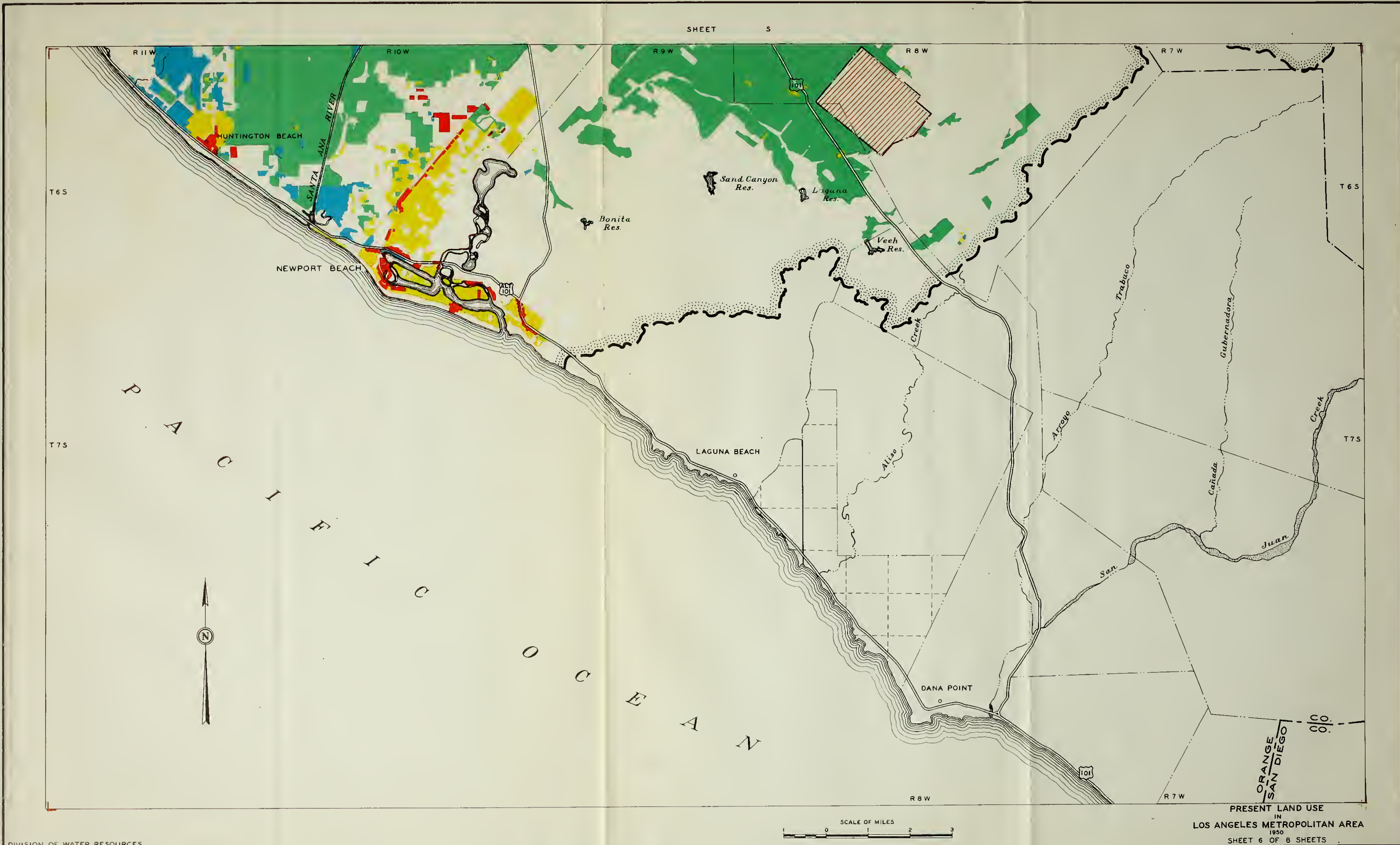
DIVISION OF WATER RESOURCES



PRESENT LAND USE
IN
LOS ANGELES METROPOLITAN AREA
1950
SHEET 4 OF 8 SHEETS

DIVISION OF WATER RESOURCES

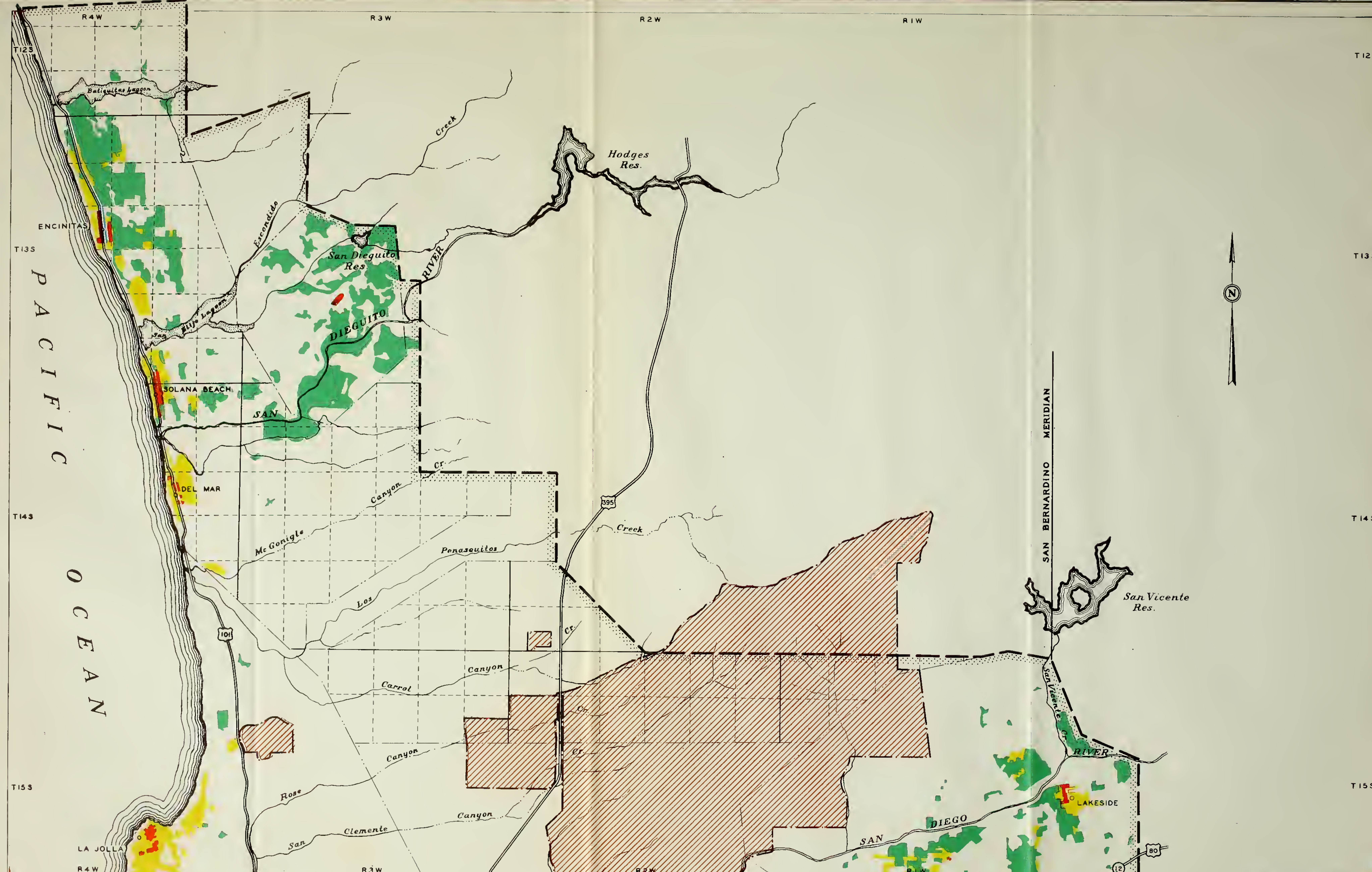

SHEET 3
SHEET 4
SHEET 6
LOS ANGELES CO.
ORANGE CO.
SAN BERNARDINO CO.
ORANGE CO.
SAN BERNARDINO
RIVERSIDE
RIVERSIDE
ORANGE
PRADO FLOOD CONTROL BASIN
LA HABRA
FULLERTON
BUENA PARK
ANAHEIM
STANTON
ORANGE
GARDEN GROVE
WESTMINSTER
SANTA ANA
SANTA ANA RIVER
Santiago Creek
Fremont Canyon
Santiago Res.
Santiago
Silverado Creek
Creek
CLEVELAND NATIONAL FOREST
R11W
R10W
R9W
R8W
R7W
T3S
T4S
T5S
101
18
91
22
DIVISION OF WATER RESOURCES
SCALE OF MILES
1 0 1 2 3
PRESENT LAND USE
IN
LOS ANGELES METROPOLITAN AREA
1950
SHEET 5 OF 8 SHEETS



PRESENT LAND USE IN LOS ANGELES METROPOLITAN AREA 1950

SHEET 6 OF 8 SHEETS

DIVISION OF WATER RESOURCES

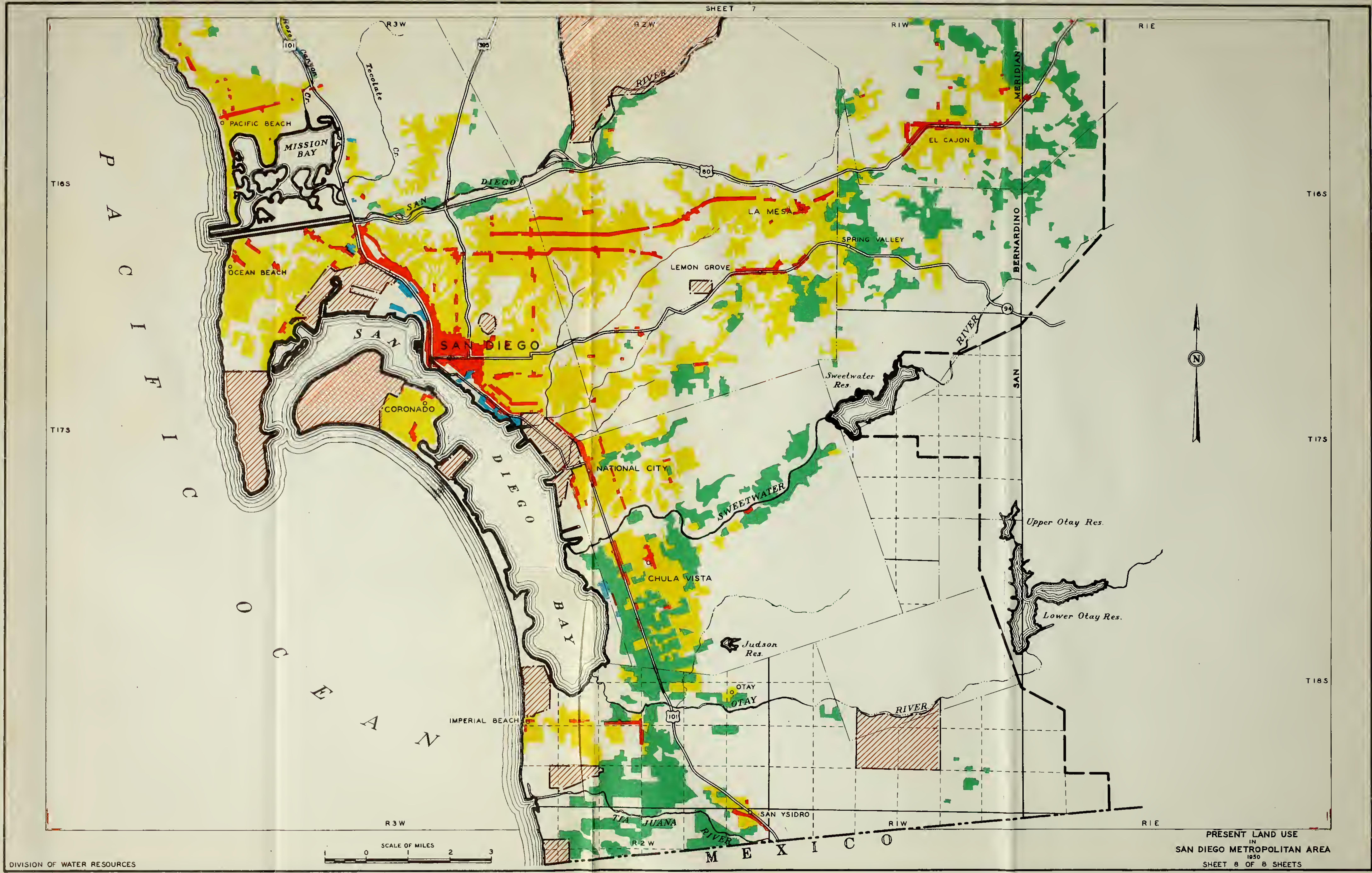


SHEET 8

SCALE OF MILES
1 0 1 2 3

DIVISION OF WATER RESOURCES

PRESENT LAND USE
IN
SAN DIEGO METROPOLITAN AREA
1950
SHEET 7 OF 8 SHEETS



PRESENT LAND USE
IN
SAN DIEGO METROPOLITAN AREA
1950
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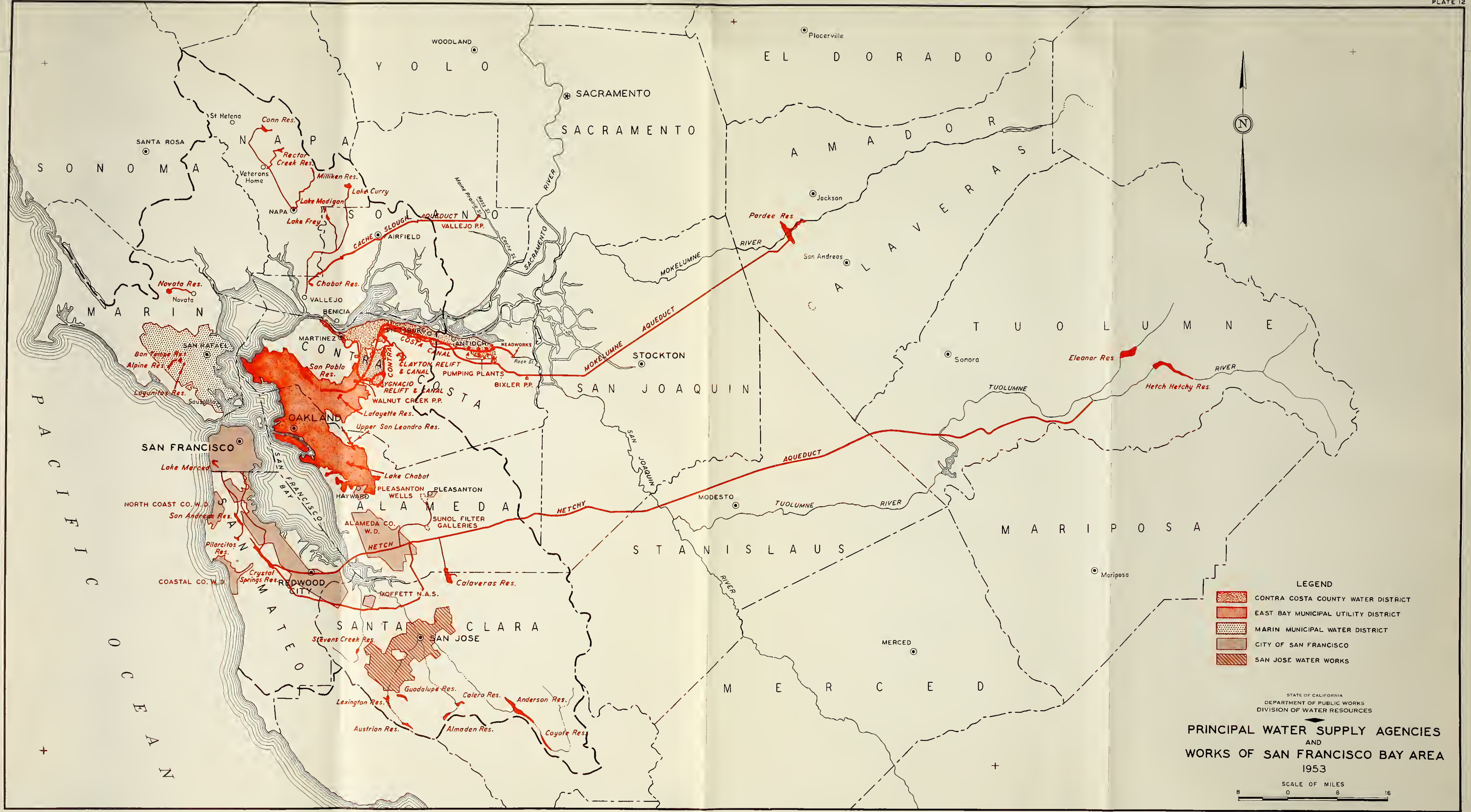
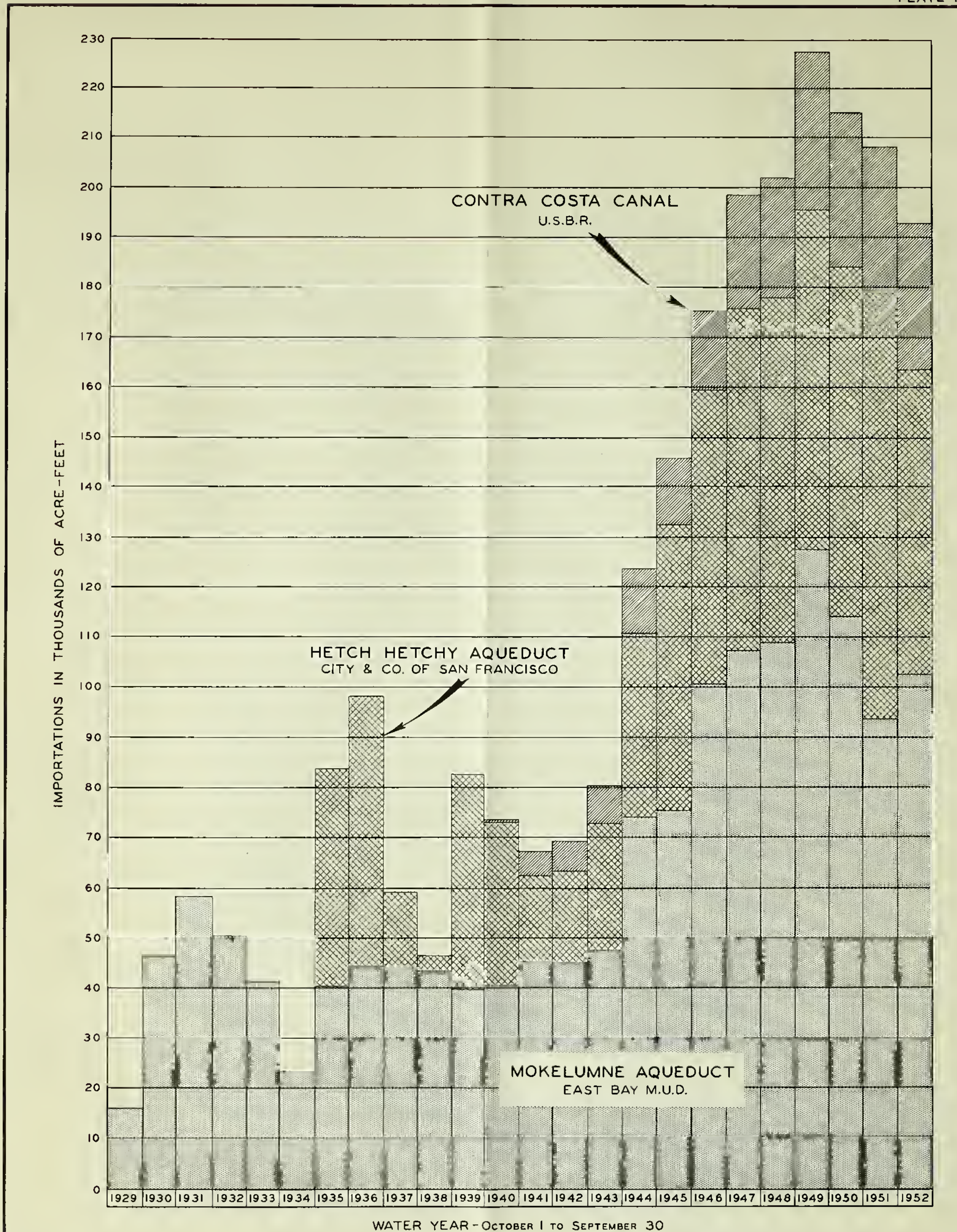


STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES

PRINCIPAL WATER SUPPLY AGENCIES AND WORKS OF SAN FRANCISCO BAY AREA

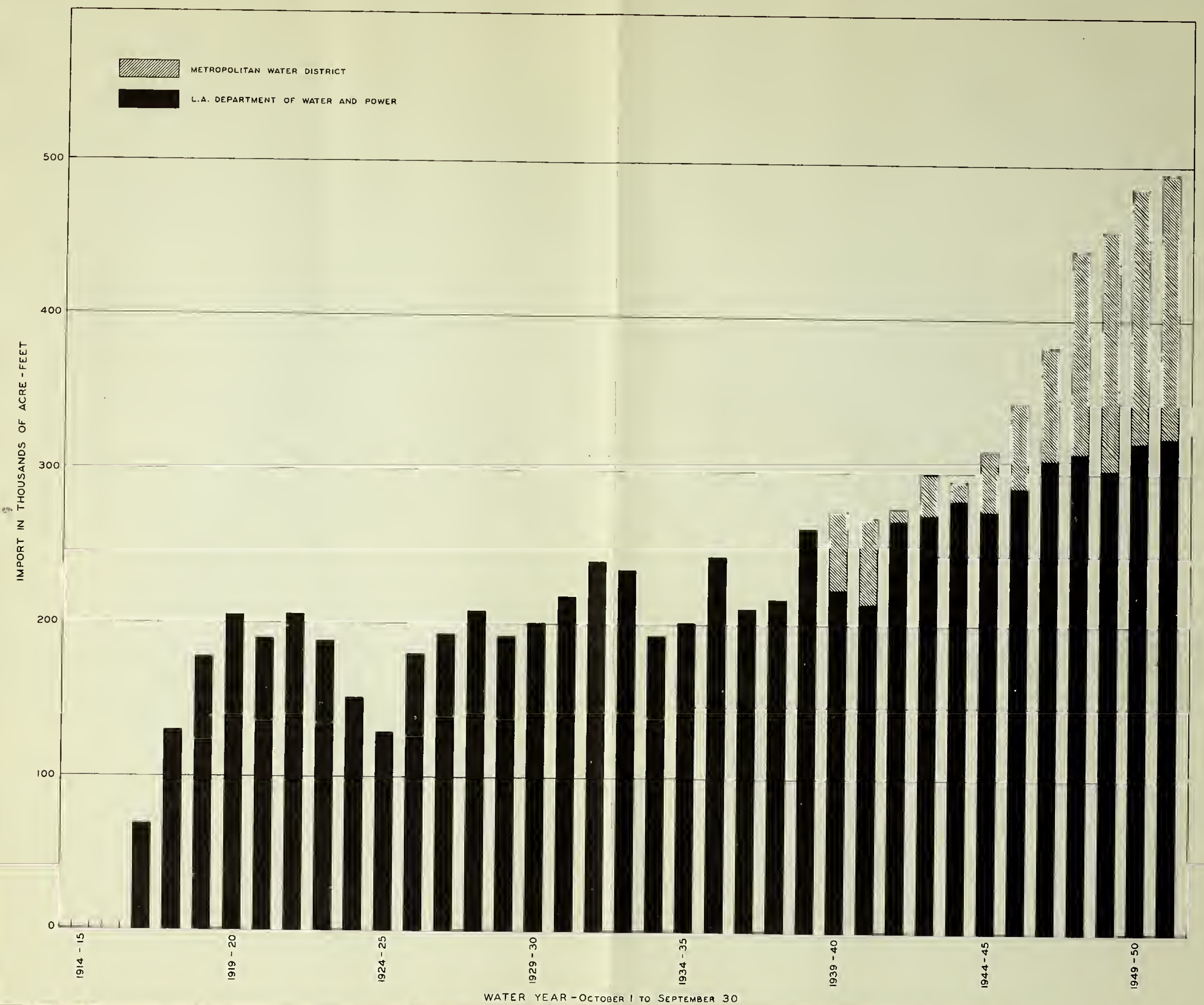
1953


REGIONAL MAP SHOWING SOURCES OF IMPORTED SUPPLY
SCALE OF MILES
MEMBERS OF THE METROPOLITAN WATER DISTRICT
LOS ANGELES
BEVERLY HILLS
BURBANK
SANTA MONICA
WEST BASIN M. W. D.
COMPTON
TORRANCE
LONG BEACH
FOOTHILL M. W. D.
GLENDALE
PASADENA
SAN MARINO
POMONA VALLEY M. W. D.
CHINO BASIN M. W. D.
FULLERTON
ANAHEIM
SANTA ANA
COASTAL M. W. D. (INCLUDING BREA)
ORANGE COUNTY M. W. D.
EASTERN M. W. D.
SAN DIEGO COUNTY WATER AUTHORITY
MEMBERS OF THE SAN DIEGO COUNTY WATER AUTHORITY
SAN DIEGO
FALLBROOK P. U. D.
OCEANSIDE
SAN DIEQUITO I. D.
ESCONDIDO
SANTA FE I. D.
LAKESIDE I. D.
LA MESA, LEMON GROVE & SPRING VALLEY I. D.
NATIONAL CITY
SOUTH BAY I. D.
CREST P. U. D.
STATE OF CALIFORNIA
DEPARTMENT OF PUBLIC WORKS
DIVISION OF WATER RESOURCES
PRINCIPAL WATER SUPPLY AGENCIES
AND
WORKS OF LOS ANGELES AND SAN DIEGO
METROPOLITAN AREAS
1953
SCALE OF MILES
PACIFIC OCEAN
MEXICO
LOS ANGELES AQUEDUCT
COLORADO RIVER AQUEDUCT
SAN DIEGO AQUEDUCT
SALTON SEA
PARKER DAM
LOS ANGELES
SAN DIEGO
PASADENA
LONG BEACH
SANTA MONICA
SAN BERNARDINO
RIVERSIDE
POMONA



IMPORTED WATER SUPPLIES OF SAN FRANCISCO BAY AREA

DIVISION OF WATER RESOURCES



IMPORTED WATER SUPPLIES OF LOS ANGELES AND SAN DIEGO METROPOLITAN AREAS

DIVISION OF WATER RESOURCES